Report No. NAWCADWAR-95040-4.6

QUANTITATIVE EVALUATION OF HIGH-PERFORMANCE FLIGHT IN A SUPINE CREW STATION USING THE NAWC DYNAMIC FLIGHT SIMULATOR-EFFECTS OF BODY POSITION AND MOTION

Barry S. Shender, PH.D. and Peggy Heffner, M.S.
HUMAN PERFORMANCE TECHNOLOGY BRANCH (Code 4.6.4.1)
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION WARMINSTER
P.O. Box 5152
Warminster, PA 18974-0591

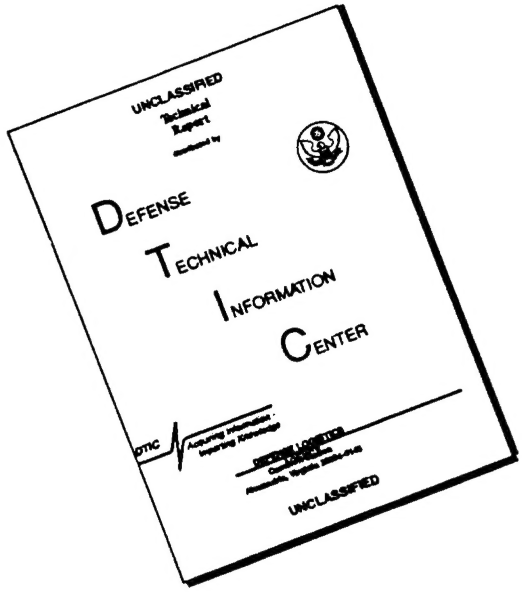
1 JUNE 1995

FINAL REPORT
Period Covering 1 September 1995 to 31 May 1995

Approved for Public Release; Distribution is Unlimited.

Prepared for
NAVAL AIR SYSTEMS COMMAND
CODE 4.6T
WASHINGTON, DC 20361-5310

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
WARMINSTER, PENNSYLVANIA 18974-0591

NAWCADWAR-95040-4.6
1 June 1995

RELEASED BY:

Donald J Harris 5-20-96

DONALD J. HARRIS / DATE
Head, Crew Systems Engineering Division
Naval Air Warfare Center Aircraft Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 JUNE 1995	1 SEPT 1994 – 31 MAY 1995

4. TITLE AND SUBTITLE

QUANTITATIVE EVALUATION OF HIGH-PERFORMANCE FLIGHT IN A SUPINE CREW STATION USING THE NAWC DYNAMIC FLIGHT SIMULATOR-EFFECTS OF BODY POSITION AND MOTION

5. FUNDING NUMBERS

PROGRAM ELEMENT
63216N

6. AUTHOR(S)

BARRY S. SHENDER, PH.D., and PEGGY HEFFNER, M.S.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

HUMAN PERFORMANCE TECHNOLOGY BRANCH (CODE 4.6.4.1)
NAVAL AIR WARFARE CENTER; AIRCRAFT DIVISION WARMINSTER
P.O. BOX 5152
WARMINSTER, PA 18974-0591

8. PERFORMING ORGANIZATION REPORT NUMBER

NAWCADWAR-95040-4.6

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

NAVAL AIR SYSTEMS COMMAND
CODE 4.6T
WASHINGTON, DC 20361-5310

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

INTRODUCTION: In an attempt to determine if high-performance supine flight is possible, the USAF Canopy Escape Module (65° supine seat) was modified and deployed into the NAWC Dynamic Flight Simulator. With its computer generated wide field of view display and HUD, aircraft controls and high fidelity high performance fighter aircraft aeromodel, it was determined if subjects could "fly" high performance maneuvers while supine. METHODS: 7 male subjects performed a flight syllabus consisting of well defined instrument flight maneuvers (vertical S-2, half Cuban 8, a series of high +Gz 360° level turns and ILS task), as defined in the NATOPS Instrument Flight Manual. Subjects were extensively trained and tested under both 1g (static) and under acceleration (dynamic) conditions in supine and upright postures. Data were assessed to determine the effects of motion (G) and seat position. A weighted objective grading scheme was devised to evaluate flight performance based on the ability to achieve specified levels of altitude, +Gz, airspeed and controllability. RESULTS: This paper reports on the analysis of the +Gz turns and the ILS task. During the turns, motion effects did not lead to significant differences in the ability to maintain specified +Gz-loads when supine, whereas there were significant differences when upright. Subjects demonstrated a

14. SUBJECT TERMS	15. NUMBER OF PAGES
SUPINE SEAT, ACCELERATION, DYNAMIC FLIGHT SIMULATION, FLIGHT PERFORMANCE, INSTRUMENT FLIGHT MANEUVERS	62
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

lower error rate while flying statically as compared to dynamically for all loads. During dynamic turns, there were no significant differences in error rates between actual and required +Gz-level, although upright subjects maintained a higher percentage of the turns within defined acceptable ranges. Even though supine, one subject did experience a +Gz induced loss of consciousness (G-LOC) and an almost LOC event during a high +Gz turn. Based on the trading scheme, subjects with the most flight hours performed somewhat better upright than supinated, while a naive subject flew significantly better supine. Overall, based the percentage of total possible points earned for each parameter, there were no statistical differences based on seating position (~4%). Based on ANCOVA results and Fisher's LSD post hoc tests, there were few statistically significant differences in flight performance during the ILS task referable on body position or effects of motion. CONCLUSIONS: High performance supine flight is feasible and additional study is warranted. Performance was definitely influenced and was reportedly more realistic under dynamic conditions.

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of Carl Pierce for his contribution towards the assuring the mechanical integrity of the supine crew station installation, Doug Waldman for calculating the "ideal" onset profiles for the high +Gz turns and the members of Biomedical Support Branch (Code 4.6.4.2) and the Crew Systems Facilities Engineering Branch (Code 4.6.2.3) without whose assistance this project would not have been possible.

CONTENTS

	Page
LIST OF TABLES	ii
LIST OF ILLUSTRATIONS	iii
BACKGROUND	1
METHODS	1
FLIGHT PERFORMANCE ASSESSMENT SCHEME	5
RESULTS	14
G TURN ANALYSIS	14
Effects of Seat Position On The Ability to Maintain Constant Acceleration Turns	14
Effects of Motion On The Ability to Maintain Constant Acceleration Turns	18
Effects of Onset/Offset Rate on Flight Performance	19
G Turn Performance Grades	20
Effects of Fatigue on Performance	20
ILS LANDING TASK ANALYSIS	23
QUESTIONNAIRE RESULTS	24
Subjective Assessment of Respiratory Effort	30
Human Factors Results	31
Loss of Consciousness	32
CONCLUSIONS	32
REFERENCES	35
APPENDIX A. G-TURN DATA	42
APPENDIX B. ILS MANEUVER DATA	
APPENDIX C. QUESTIONNAIRE	

LIST OF TABLES

Page

1. Vertical S-2 description 3
2. Description of the high G level turns (OSCAR pattern) 3
3. Description of the Half Cuban Eight maneuver 4
4. Description of the three segments of the ILS landing task 4
5. Subjective level of respiratory effort, based on modified Borg Scale (10) 5
6. Criteria for "Good" and "Fair" performance during G turns 6
7. Rating scheme for G turns 6
8. Points awarded for maintaining target G level during turns 7
9. Points awarded for maintaining target airspeed level during G turns 8
10. Points awarded for controllability 8
11. Points awarded for maintaining target altitude level during G turns 9
12. Points awarded for achieving a 360° arc during each turn 9
13. Criteria for "Good," "Fair" and "Poor" performance during ILS task 10
14. Points awarded for maintaining target altitude during ILS approach 11
15. Points awarded for maintaining target airspeed during ILS approach 11
16. Points awarded for maintaining target heading and vertical airspeed during ILS approach 12
17. Points awarded for maintaining target altitude during Glide Slope 12
18. Points awarded for maintaining target airspeed during Glide Slope 13
19. Points awarded for maintaining target heading during Glide Slope 13
20. Points awarded for maintaining target vertical airspeed during Glide Slope 14
21. Points awarded while at the glide slope intercept, at the decision point and for the minimum altitude during wave off 14
22. Mean G performance for subject pool during G turns for static data runs 15
23. Mean G performance for subject pool during G turns for dynamic data runs 16
24. Interactions between regressors during analysis of the subjects' ability to maintain required G levels during the OSCAR pattern indicated by ANCOVA tests 16
25. Mean airspeed performance for subject pool during G turns for static data runs 16
26. Mean airspeed performance for subject pool during G turns for dynamic data runs 17
27. Interactions between ANCOVA regressors found during analysis of airspeed parameters during performance of G turns 17
28. Mean altitude performance for subject pool during G turns for static data runs 17
29. Mean altitude performance for subject pool during G turns for dynamic data runs 18
30. Interactions between ANCOVA regressors found during analysis of altitude parameters during performance of G turns 18
31. Ideal and mean values during onset into the G turns 21
32. Mean values during offset from the G turns 22
33. Piloting performance grades during G turns for subject population 23
34. Mean subject pool flight parameters during ILS approach 25
35. Mean subject pool flight parameters while following the glide slope towards the decision point 26
36. Mean flight parameters at the intercept with the glide slope, at the decision point to wave off and the minimum altitude during the wave off 27
37. Flight performance scores for the ILS task 28
38. Interactions between regressors during analysis of the subjects' ability to maintain required flight parameters during the ILS task indicated by ANCOVA tests 28
39. Mean upright questionnaire responses 29
40. Mean supine questionnaire responses 30

LIST OF ILLUSTRATIONS

Page

1. Modified Vertical S2 Maneuver 36
2. The High-G Turn Maneuvers (Oscar Pattern) are based on the standard Oscar pattern, but substituting constant acceleration turns for the standard rate turns 36
3. The Half Cuban Eight Maneuver is a standard maneuver 37
4. The ILS task begins when the subject brings the aircraft to an altitude of 1,200 ft, then the ILS indicators are activated and the aeromodel automatically places the nose of the aircraft 8 nm from the runway 37
5. Example of $11G_{radial}$ turn performance while supine for Subject S1 as compared to the Ideal profile 38
6. Example of +9 Gz turn performance while upright for Subject S1 as compared to the Ideal profile 38
7. Example of ILS performance while supine for Subject S1 as compared to the Ideal profile 39
8. Example of ILS performance while upright for Subject S1 as compared to the Ideal profile 39
9. Control stick and rudder pedal movements during Subject S2 +11 Gz supine turn prior to loss of consciousness events 40
10. Control stick and rudder pedal movements during Subject S2 +11 Gz supine turn during almost loss of consciousness episode 41

BACKGROUND

It has been shown since the 1930's that an individual in a supine position has an increased tolerance to acceleration stress, as compared to an upright posture. This is due to the reduced effective height of their hydrostatic column between the heart and the brain (1-4). Because of this change in posture, the resultant +Gz vector has shifted from the usual head-to-foot orientation. The magnitude of the +Gz load is given by

$$+Gz = (\text{Resultant G}) * \cos(\text{SBA} - 15),$$

where SBA (seat-back-angle) is relative to a perpendicular vertical reference. For example, as compared to the +10 Gz load imposed on a pilot flying in a standard upright 15° SBA seat, when the SBA is increased to 60°, the equivalent stress becomes +7.1 G. This finding has led to proposals which include supinated seats in advanced tactical crew stations to ameliorate the effects of high-G loading.

In-flight evaluation of supinated seats began in the 1930's in Germany using gliders with and without engines. In 1940 in the U.K., a 50° SBA seat was flown in a Fairey Battle K-9289 Light bomber (4). Gell and Hunter (2) reported that G-tolerance, as measured during 5 s centrifuge exposures, began to increase after subjects were tilted back to 45°. A 2.5 G increase in tolerance was demonstrated at 77° SBA. They did find that at 65° SBA and higher, pressure on the thorax and abdomen became pronounced and to some degree hindered respiration, particularly at 85° SBA. This reclined seat concept was installed in the rear cockpit of a Grumman F7F-2N "Tigercat" in 1951. It was not favorably evaluated by its test pilot. The PALE (pelvis and legs elevating) seat was flown in a Sikorsky CH 53-A in 1979 (4). In this concept the head remained fixed relative to the displays and the legs and pelvis were raised to reduce the hydrostatic column height. The PALE flight test did receive a satisfactory evaluation.

This investigation addressed two basic questions. The first was to determine whether or not humans could fly modern high performance aircraft in a reclined position. Flying in this position presents a host of questions, particularly in the area of air-to-air combat and take-off / landing procedures. Some of the basic design problems to overcome when using a supinated seat include ejection and visibility issues, particularly displays and controls and the ability to see the nose of the aircraft. The second investigated the need for dynamic flight simulation, which included the acceleration forces generated in flight, as compared to static flight simulation without such cues. Even though the quality of ground based simulators has improved over the years, the need to include such bodily sensations was been promoted since the early 1970's (5,6).

METHODS

To address these issues, NAWCADWAR has conducted the first in a series of evaluations using the NAWCADWAR Dynamic Flight Simulator (DFS). The USAF Canopy Escape Module (7) (65° seat back angle, SBA) was modified and deployed in the DFS. Given

the limitations of the visual display currently installed in the DFS, 7 male subjects (ranging in flight experience from naive to fighter pilots) performed a flight syllabus consisting of basic instrument flight maneuvers, including vertical S-2, half Cuban eight, a series of high-G 360° level turns and ILS (instrument landing system) landing maneuvers. The first three of these tasks are defined in the NATOPS Instrument Flight Manual (8) and the latter outlined in the NATOPS Flight Manual (9) and form the basis of all air-to-air and air-to-ground maneuvers. Proficiency in these maneuvers is required of every USN student pilot. Therefore, in order fly supinated, it follows that one must still be able to execute these NATOPS maneuvers. Note that all subjects gave their informed consent under SECNAVINST 3900.39B, "Protection of Human Subjects", 27 Feb 1984.

A high fidelity high performance fighter aircraft aeromodel was custom designed to simulate flight characteristics ranging from high acceleration high altitude to low speed low altitude conditions. This was coupled with a computer generated wide field of view visual system, F/A-18 style Heads Up Display (HUD), side arm stick controller, throttle, rudder pedals, switches to activate flaps, landing gear, speed brakes, event marker and ILS indicators. Subjects were in two way audio communications contact with the flight deck and were monitored with two video cameras. Subjects wore a CSU-13/P anti-G suit, flight suit, TacAir helmet, low profile mask and torso harness. No pressure breathing was employed or breathing gas was supplied. The mask was used to determine whether it would interfere with the line of sight during supine flight. Medical monitoring included two sets of electrocardiograph leads located sternally and biaxillary, infrared plethysmograph on the ear to monitor head level blood velocity and respiratory function (Respitrace Plus™, Non-invasive Monitoring Systems, Inc., Miami Beach, FL). Aircraft data recorded included airspeed, altitude, ±Gz, ±Gx, ±Gy, entry/exit heading and location, bank, pitch, yaw and roll angles and elapsed time per maneuver.

Subjects were trained at 1g (static) and under acceleration (dynamic) to perform the flight syllabus in both upright and supine postures. Static training averaged 9.75 hours. Dynamic training (average 3.25 hours) consisted of two separate G-limited insertions in the DFS. The first upright limit was +4 Gz and the second was +7 Gz, and the supine limits were +5.5 G and +8 G, respectively. During data collection phases, the four maneuvers were repeated twice per insertion in the gondola for a total of two repetitions in the static mode and four in the dynamic mode. The sequence of maneuvers in the syllabus was ILS landing, Half Cuban Eight, Vertical S-2, high-G turns, five minute break, Half Cuban Eight, Vertical S-2, high-G turns and ILS landing.

Each of the maneuvers were well defined and subjects were trained to attain specific flight parameters. The Vertical S-2 was a series of constant rate (350 KCAS - knots equivalent air speed) climbs and descents (1,000 fpm vertical airspeed) at a 45° bank angle resulting in a +1.4 Gz turn. The maneuver can be described as four segments (see Fig. 1 - the different shading in the figure denotes to individual segments). The sequence of these segments is shown in Table 1.

The series of high-G turns (based on the OSCAR pattern) consisted of a coordinated series of 360° level turns at 10,000 ft with a vertical velocity of 0 FPM throughout. For this pattern, entry and exit heading were the same. When upright, the turns were +5 Gz to the right ("low" G), then +7 Gz to the left ("medium" G), then to the +9 Gz right ("high" G). For the supine position, the corresponding G loads (G_{radial}, i.e. G imposed on the gondola) were +7 ("low" G), +9 ("medium" G) and +11 ("high" G). This pattern consisted of seven segments as listed in Table 2 and shown in Fig. 2.

Segment	Description	Initial Altitude (feet)	Vertical Velocity	Duration	Turn Rate	End Altitude (feet)
1	Straight & Level	10,000	0 FPM	15 s	0	10,000
2	Descending Right Turn	10,000	-1,000 FPM	180° heading change ≈ 60 s	45° bank (1.4 G), 180°/min	9,000
3	Climbing Right Turn	9,000	1,000 FPM	180° heading change ≈ 60 s	45° bank (1.4 G), 180°/min	10,000
4	Straight & Level	10,000	0 FPM	15 s	0	10,000

Table 1. Vertical S-2 description.

		Upright			Supine		
Segment	Description	Airspeed (KCAS)	Duration (seconds)	+Gz Load	Airspeed (KCAS)	Duration (seconds)	G Load (G_{radial})
1	Straight & Level	450	15	1	450	15	1
2	Sustained Acceleration Left Turn	450	30	5	450	22	7
3	Straight & Level	450	15	1	500	15	1
4	Sustained Acceleration Right Turn	450	22	7	500	17	9
5	Straight & Level, Accelerating	500	30	1	500	30	1
6	Sustained Acceleration Left Turn	500	17	9	500	14	11
7	Straight & Level	500	15	1	500	15	1

Table 2. Description of the high G level turns (OSCAR pattern).

The Half Cuban Eight maneuver was set up at 10,000 ft and 450 KCAS. Then a constant G pull up was initiated (about +6 Gz) until 10° angle of attack (AOA) was achieved. The subject held that AOA until a 45° nose low inverted dive was attained, followed by a roll upright, with a 10° AOA constant G pull-up to complete a 180° course reversal back at the entrance altitude. Its six segments are listed in Table 3 and shown in Fig. 3.

For the Instrument Landing System (ILS) task subjects were provided with an ILS display, including a Glide Slope Indicator (horizontal line which indicates the deviation from the optimum pitch angle and airspeed - glide slope angle was 3.5°) and a Course Deviation Indicator (vertical line which indicates the deviation from the center of the runway - a deflection to the right of center requires a course adjustment to the right) overlaid onto the HUD. They then performed a "landing in the sky," that is, come within sight of the runway and then wave off. To minimize maneuvering time, the aeromodel was automatically positioned 8 nm from the nose of the aircraft when the ILS was activated. Subjects set up at 1,200 feet, 170 KCAS at a heading of 90°. When they intercepted the glide slope, they descended at 830 FPM and waved off at 200 feet, 3,900 feet from the runway. The entire landing procedure took about 5 min. This maneuver's three segments are listed in Table 4 and displayed in Fig. 4.

Segment	Description	Initial Altitude (feet)	Vertical Velocity	Duration	End Attitude	Turn Rate/ A/C Load	End Altitude (feet)
1	Straight & Level	10,000	0 FPM	15 s		0	10,000
2	Constant G Loop	10,000	varies	until 10° AOA	N/C	6 G	N/C
3	Constant AOA Loop	N/C	varies	until end attitude achieved	45° nose low, inverted	6 G	N/C
4	Diving Roll	N/C	varies	until upright	45° nose low	6 G	N/C
5	Pull Out	≈ 12,500	varies	45° bank	Level	6 G	≈ 10,000
6	Straight & Level	10,000	0 FPM	30 s	Level	0	10,000

Table 3. Description of the Half Cuban Eight maneuver. N/C: not critical.

Segment	Description	Entry Altitude	Vertical Velocity	Entry Distance	End Distance	Airspeed	End Altitude
1	Straight & Level, configure for landing	1,200 ft	0	8 nm	4.3 nm	170 KCAS	1,200 ft
2	Final approach, push over at glide slope intercept	1,200 ft	-830 FPM	4.3 nm	0.75 nm	170 KCAS	200 ft
3	Missed approach, wave off	200 ft	2,000 FPM for 30 sec	0.75 nm	N/C	N/A	N/C

Table 4. Description of the three segments of the ILS landing task. N/C: not critical.

Two different categories of data assessment were performed: effects of motion and seat position. These determinations were calculated for individual subjects as well as for the entire group. A weighted objective grading scheme was devised (based on instructor pilot experience) to evaluate flight performance based on the ability to achieve specified levels of acceleration,

altitude and airspeed, as well as an index of controllability (based on a linear model) and flight experience. Statistical tests included paired t (Microsoft Excel ver. 5.0a, Microsoft Corp., Redmond, WA) and analysis of covariance (ANCOVA) with a post hoc Fisher's Least Square Difference test to determine interactions (Number Cruncher Statistical System, ver. 5.0, Kaysville, Utah). Statistical significance was set at the $p \leq 0.05$ level. A full linear model was used for the ANCOVA and any main effects or interactions which were not significant ($p > 0.05$) were deleted and the analysis was repeated with a reduced model. For the G turns, a one factor (flight parameter) x four regressor (body position, motion, G level, flight experience) model was used and for the ILS task a one factor (flight parameter) x three regressor (body position, motion, flight experience) model was used. Subjects were given a questionnaire (Appendix C) after each dynamic run to subjectively assess their comfort, ability to reach and see the instruments and their flight performance. These responses were tested for significant differences based on seat position using a Chi Square test. When an individual is supinated, the +Gz vector is oriented through the chest, rather than vertically along the spine, which can hinder full expansion of the chest during respiration. To assess the subjective difficulty in breathing under dynamic conditions, subjects were ask to rate their breathing effort using a modified Borg scale (10) in both body positions (Table 5).

Numerical Score	Descriptor
0	NO EFFORT
0.5	VERY, VERY SLIGHT EFFORT
1	VERY SLIGHT EFFORT
2	SLIGHT EFFORT
3	MODERATE EFFORT
4	SOMEWHAT STRONG EFFORT
5	STRONG EFFORT
6	
7	VERY STRONG EFFORT
8	VERY, VERY STRONG EFFORT
9	
10	MAXIMAL RESPIRATORY EFFORT

Table 5. Subjective level of respiratory effort, based on modified Borg Scale (10).

FLIGHT PERFORMANCE ASSESSMENT SCHEME

This interim report contains the analysis of the high-G turns and the ILS task. The following describes how the high-G turns were evaluated. To determine how close subjects "flew" to the syllabus requirements, actual G-load, airspeed and altitude data were compared to target profiles using correlation analyses (r) and the sum of squared errors from the target profile (SSE target) was calculated. Ranges for "good," "fair" and "poor" performance (Range) were established based on instructor pilot experience (Table 6) and the percentage of the turn spent in these ranges was calculated. The most controlled performance had the fewest oscillations about the target profile so the sum of squared errors of the actual G level from the actual mean was calculated (SSE mean) and, given that the profiles were constant acceleration turns, calculating an r^2 value of actual G level over time provided an additional index of controllability. For

grading purposes, individual SSE values were compared to the overall group averaged SSE mean for each parameter as outlined in the Tables below. A weighted objective grading scheme was devised to evaluate flight performance (Table 7). This included (in order of decreasing weight) the ability to maintain target G level (Table 8), airspeed (Table 9), controllability (based on a linear model, Table 10), altitude (Table 11) and to achieve a full 360° turn (Table 12). An index of flight experience was used as an additional regressor in the ANCOVA. Table 33 lists the flight experience of the subject pool. For ANCOVA tests, subject were grouped as flight instructor (S1), extensive flight experience in a variety of platforms (S2), experience in high-G trainer aircraft (S3, S4), private aircraft experience (S6, S7) and naive (S5).

Performance during onset and offset from the G turns was compared against theoretical curves based on ideal aeromodel performance, as well as for motion and body position effects. Parameters included time, G rate, altitude, heading and roll angle.

To assess the effects of motion on performance, static versus dynamic data sets were compared for each position separately, e.g. upright static versus upright dynamic performance. The effects of body position were determined by comparing upright static versus supine static and upright dynamic versus supine dynamic performances. These comparisons were calculated for individual subjects as well as for the entire group. In addition to these assessments, an indication of whether fatigue was a performance limiting factor during dynamic runs was determined based on differences between the first and last sets of G turns and ILS landings. Note that this run order was used instead of motion as a regressor in ANCOVA tests.

Parameter	Good Range	Fair Range
Low G	± 0.2 G	± 0.3 G
Medium G	± 0.5 G	± 0.75 G
High G	± 1.0 G	± 1.5 G
Airspeed	± 10 KCAS	± 20 KCAS
Altitude	± 100 feet	± 300 feet

Table 6. Criteria for "Good" and "Fair" performance during G turns.

Priority	Factor	Weight	Total points	Parameters		
1	G level	0.36	36	Range	SSE from target	r between actual & target
2	Airspeed	0.21	21	Range	SSE from target	r between actual & target
3	controllability	0.18	18	SSE from mean G		r^2 of actual - test for linearity
4	altitude	0.15	15	Range	SSE from target	r between actual & target
5	heading	0.10	10	Proximity to 360°		

Table 7. Rating scheme for G turns. Scores: excellent ≥ 90, 80 ≤ good < 90, 75 ≤ average < 80, 65 ≤ fair < 75, poor < 65 points. The ability the maintain target G level, airspeed and altitude was based on percentage of time in the acceptable Ranges, SSE from target levels and the correlation between actual performance and the target profiles. Controllability scores were based on a deviation from a linear (constant acceleration turn) G profile and included SSE of the actual G level from the actual mean and the r^2 value of actual G over time. Heading ratings were based on how close the subjects completed a full 360° turn.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	8	8	$75 \le GR \le 100$	"Fair" Range Percentage (FR)	4	4	$75 \le FR \le 100$
		6	$50 \le GR < 75$			3	$50 \le FR < 75$
		4	$25 \le GR < 50$			2	$25 \le FR < 50$
		2	$10 \le GR < 25$			1	$10 \le FR < 25$
		1	$0 < GR < 10$			0.5	$0 < FR < 10$
		0	0			0	0
SSE Target G	12	12	≤ 9% * mean	SSE Target G (con'd)			
		11	≤ 18% * mean			5	≤ 72% * mean
		10	≤ 27% * mean			4	≤ 81% * mean
		9	≤ 36% * mean			3	≤ 90% * mean
		8	≤ 45% * mean			2	≤ 99% * mean
		7	≤ 54% * mean			1	≤ 108% * mean
		6	≤ 63% * mean			0	> 108% * mean
Correlation between G and ideal (r)	12	12	$0.92 \le r \le 1.00$	Correlation between G and ideal (r) (con'd)			
		11	$0.84 \le r < 0.92$			5	$0.36 \le r < 0.44$
		10	$0.76 \le r < 0.84$			4	$0.28 \le r < 0.36$
		9	$0.68 \le r < 0.76$			3	$0.20 \le r < 0.28$
		8	$0.60 \le r < 0.68$			2	$0.12 \le r < 0.20$
		7	$0.52 \le r < 0.60$			1	$0.04 \le r < 0.12$
		6	$0.44 \le r < 0.52$			0	< 0.04

Table 8. Points awarded for maintaining target G level during turns based on (1) percentage of values in "good" or "fair" range; (2) sum squared error (SSE) between actual and target G levels where "mean" is the average SSE for the subject pool and (3) the value of the correlation between actual and target G level.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	4	4	75 ≤ GR ≤ 100	"Fair" Range Percentage (FR)	3	3	70 ≤ FR ≤ 100
		3	50 ≤ GR < 75			2	40 ≤ FR < 70
		2	25 ≤ GR < 50			1	10 ≤ FR < 40
		1	10 ≤ GR < 25			0.5	0 < FR < 10
		0.5	0 < GR < 10			0	0
		0	0				
SSE Target airspeed	7	7	≤ 14% * mean	SSE Target airspeed (con'd)			
		6	≤ 28% * mean			2	≤ 84% * mean
		5	≤ 42% * mean			1	≤ 98% * mean
		4	≤ 56% * mean			0.5	≤ 112% * mean
		3	≤ 70% * mean			0	> 112% * mean
Correlation between airspeed and ideal (r)	12	7	0.86 ≤ r ≤ 1.00	Correlation between airspeed and ideal (r) (con'd)			
		6	0.72 ≤ r < 0.86			2	0.16 ≤ r < 0.30
		5	0.58 ≤ r < 0.72			1	0.02 ≤ r < 0.16
		4	0.44 ≤ r < 0.58			0.5	0.0 < r < 0.02
		3	0.30 ≤ r < 0.44			0	0

Table 9. Points awarded for maintaining target airspeed level during G turns based on (1) percentage of values in "good" or "fair" range; (2) sum squared error (SSE) between actual and target airspeed levels where "mean" is the average SSE for the subject pool and (3) the value of the correlation between actual and target airspeed level.

Factor	Total Points	Points	Distribution	Factor	Points	Distribution
SSE Mean +Gz	9	9	≤ 11% * mean	SSE Mean +Gz (con'd)		
		8	≤ 22% * mean		3	≤ 77% * mean
		7	≤ 33% * mean		2	≤ 88% * mean
		6	≤ 44% * mean		1	≤ 99% * mean
		5	≤ 55% * mean		0.5	≤ 110% * mean
		4	≤ 66% * mean		0	> 110% * mean
Test for linearity (r^2)	9	9	$0.89 \le r^2 \le 1.00$	Test for linearity (r^2) (con'd)		
		8	$0.78 \le r^2 < 0.89$		3	$0.23 \le r^2 < 0.34$
		7	$0.67 \le r^2 < 0.78$		2	$0.12 \le r^2 < 0.23$
		6	$0.56 \le r^2 < 0.67$		1	$0.01 \le r^2 < 0.12$
		5	$0.45 \le r^2 < 0.56$		0	$0.01 < r^2$
		4	$0.34 \le r^2 < 0.45$			

Table 10. Points awarded for controllability as calculated by determining the SSE from the mean G level during the turn and if the G values during the turn varied in a linear fashion. "* mean" refers to the average SSE Mean for the subject pool.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range	3	3	$70 \le GR \le 100$	"Fair" Range	2	2	$50 \le FR \le 100$
Percentage		2	$40 \le GR < 70$	Percentage		1	$10 \le FR < 50$
(GR)		1	$10 \le GR < 40$	(FR)		0.5	$0 < FR < 10$
		0.5	$0 < GR < 10$			0	0
		0	0				
SSE Target altitude	5	5	$\le 20\% *$ mean	SSE Target altitude (con'd)			
		4	$\le 40\% *$ mean			1	$\le 100\% *$ mean
		3	$\le 60\% *$ mean			0.5	$\le 120\% *$ mean
		2	$\le 80\% *$ mean			0	$> 120\% *$ mean
Correlation between altitude and ideal (r)	12	5	$0.80 \le r \le 1.00$	Correlation between altitude and ideal (r) (con'd)			
		4	$0.60 \le r < 0.80$			1	$0.10 \le r < 0.20$
		3	$0.40 \le r < 0.60$			0.5	$0.00 < r < 0.10$
		2	$0.20 \le r < 0.40$			0	0

Table 11. Points awarded for maintaining target altitude level during G turns based on (1) percentage of values in "good" or "fair" range; (2) sum squared error (SSE) between actual and target altitude levels where "mean" is the average SSE for the subject pool and (3) the value of the correlation between actual and target altitude level.

Factor	Total Points	Points	Distribution
Turn circumference	10	10	$350° \le$ circumference $\le 370°$
		6	$340° \le$ circumference $< 380°$
		2	$330° \le$ circumference $< 390°$
		0	$390° <$ circumference $< 330°$

Table 12. Points awarded for achieving a 360° arc during each turn.

The following describes how the ILS task was evaluated. Performance ratings were based on the ability to maintain target altitude, airspeed, heading, vertical airspeed and an index of controllability. The task was separated into performance (1) during the approach (Approach), (2) at the glide slope intercept (Intercept), (3) following the glide slope towards the runway (Glide Slope), (4) at the decision point (i.e. when to begin to wave off) and (5) the minimum altitude during the wave off. In a similar fashion to the G turn analysis, actual altitude, airspeed, heading, vertical airspeed were compared to ideal profiles using correlation analyses and the SSE from the target profile were calculated. Performance ranges were established based on instructor pilot experience (Table 13) and the percentage of each segment spent in these ranges calculated. During the Glide Slope, since the aircraft was flying close to stall speed, airspeed had to be at least 170 KCAS and the descent should not have exceeded -1,000 feet per minute. Minimum allowed altitude during the waveoff was set to 150 feet. Controllability was determined in a similar fashion to the G turns except that the SSE from the mean altitude (during

ILS approach only), airspeed, heading and vertical airspeed were determined and compared to the group mean SSE values. A weighted objective grading scheme was devised to evaluate flight performance. For performance during the Approach, the grading scheme for altitude (Table 14), airspeed (Table 15) and heading and vertical airspeed (Table 16) are given below. Tables 17 (altitude), 18 (airspeed), 19 (heading) and 20 (vertical airspeed) detail the grading scheme for the Glide Slope. Table 21 contains the grading scheme for flight parameters at the Intercept, at the decision point and the minimum altitude during wave off. In a similar fashion to the G turn assessment, the effects of motion, seat position, fatigue and flight experience were determined.

Target Parameter	Good Range	Fair Range	Poor Range
During Approach	and at Intercept:		
1200 ft Altitude	± 50 ft	± 75 ft	1125 < feet > 1275
170 KCAS	± 5 KCAS	± 10 KCAS	160 < KCAS > 180
90° Heading	± 1°	± 2°	88° < heading > 92°
0 FPM Vertical Airspeed	± 75 FPM	± 125 FPM	- 125 < FPM > 125
During Glide Slope	(GS):		
Altitude along GS	± 10 ft	± 15 ft	-15 ft < GS > +15 ft
170 KCAS	170 to 180 KCAS	170 to 185 KCAS	170 < KCAS > 185
90° Heading	± 1°	± 2°	88° < heading > 92°
-830 FPM Vertical Airspeed	-745 < FPM < -915	-660 < FPM < -1,000	- 660 > FPM < -1,000
At Decision Point:			
200 ft Altitude	± 10 ft	± 15 ft	185 ft < GS > 215 ft
170 KCAS	170 to 180 KCAS	170 to 185 KCAS	170 < KCAS > 185
90° Heading	± 1°	± 2°	88° < heading > 92°
-830 FPM Vertical Airspeed	-745 < FPM < -915	-660 < FPM < -1,000	- 660 > FPM < -1,000
Minimum Altitude:			
150 ft Altitude	≥ 150 ft	no fair category	150 ft < Altitude

Table 13. Criteria for "Good," "Fair" and "Poor" performance during ILS task.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	2	2	$85 \le GR \le 100$	"Fair" Range Percentage (FR)	1	1	$85 \le FR \le 100$
		1.5	$50 \le GR < 85$			0.75	$50 \le FR < 85$
		1	$25 \le GR < 50$			0.5	$25 \le FR < 50$
		0.5	$0 < GR < 25$			0.25	$0 \le FR < 25$
		0	0			0	0
SSE Target Altitude	1.5	1.5	< 34% * mean	SSE Mean Altitude	2	2	< 25% * mean
		1	< 67% * mean			1.5	< 50% * mean
		0.5	< 100% * mean			1	< 75% * mean
		0	> 100% * mean			0.5	< 100% * mean
						0	> 100% * mean
Correlation between Altitude and target (r)	1	1	$0.75 \le r \le 1.00$	Test for linearity (r^2)	2	2	$0.75 \le r^2 \le 1.00$
		0.75	$0.50 \le r < 0.75$			1.5	$0.50 \le r^2 < 0.75$
		0.5	$0.25 \le r < 0.50$			1	$0.25 \le r^2 < 0.50$
		0.25	$0.0 \le r < 0.25$			0.5	$0.0 \le r^2 < 0.25$
		0	0			0	0

Table 14. Points awarded for maintaining target altitude during ILS approach.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	2	2	$85 \le GR \le 100$	"Fair" Range Percentage (FR)	1	1	$85 \le FR \le 100$
		1.5	$50 \le GR < 85$			0.75	$50 \le FR < 85$
		1	$25 \le GR < 50$			0.5	$25 \le FR < 50$
		0.5	$0 < GR < 25$			0.25	$0 \le FR < 25$
		0	0			0	0
SSE Target Airspeed	1	1	< 34% * mean	SSE Mean Airspeed	1	1	< 34% * mean
		0.67	< 67% * mean			0.67	< 67% * mean
		0.34	< 100% * mean			0.34	< 100% * mean
		0	> 100% * mean			0	> 100% * mean
Correlation between Airspeed and target (r)	1	1	$0.75 \le r \le 1.00$	Test for linearity (r^2)	1	1	$0.75 \le r^2 \le 1.00$
		0.75	$0.50 \le r < 0.75$			0.75	$0.50 \le r^2 < 0.75$
		0.5	$0.25 \le r < 0.50$			0.5	$0.25 \le r^2 < 0.50$
		0.25	$0.0 \le r < 0.25$			0.25	$0.0 \le r^2 < 0.25$
		0	0			0	0

Table 15. Points awarded for maintaining target airspeed during ILS approach.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	2	2	$85 \le GR \le 100$	"Fair" Range Percentage (FR)	1	1	$85 \le FR \le 100$
		1.5	$50 \le GR < 85$			0.75	$50 \le FR < 85$
		1	$25 \le GR < 50$			0.5	$25 \le FR < 50$
		0.5	$0 < GR < 25$			0.25	$0 \le FR < 25$
		0	0			0	0
SSE Target Heading or Vertical Airspeed	1.5	1.5	< 34% * mean	SSE Mean Heading or Vertical Airspeed	2	2	< 25% * mean
		1	< 67% * mean			1.5	< 50% * mean
		0.5	< 100% * mean			1	< 75% * mean
		0	> 100% * mean			0.5	< 100% * mean
						0	> 100% * mean
Correlation between Heading or Vertical and target (r)	1	1	$0.75 \le r \le 1.00$	Test for linearity (r^2)	1	1	$0.75 \le r^2 \le 1.00$
		0.75	$0.50 \le r < 0.75$			0.75	$0.50 \le r^2 < 0.75$
		0.5	$0.25 \le r < 0.50$			0.5	$0.25 \le r^2 < 0.50$
		0.25	$0.0 \le r < 0.25$			0.25	$0.0 \le r^2 < 0.25$
		0	0			0	0

Table 16. Points awarded for maintaining target heading and vertical airspeed during ILS approach.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range Percentage (GR)	1.5	1.5	$75 \le GR \le 100$	"Fair" Range Percentage (FR)	1	1	$75 \le FR \le 100$
		1	$50 \le GR < 75$			0.75	$50 \le FR < 75$
		0.5	$25 \le GR < 50$			0.5	$25 \le FR < 50$
		0.25	$0 < GR < 25$			0.25	$0 \le FR < 25$
		0	0			0	0
SSE Target Altitude	1.5	1.5	< 34% * mean	SSE Mean Altitude			
		1	< 67% * mean				
		0.5	< 100% * mean				
		0	> 100% * mean				
Correlation between Altitude and target (r)	1	1	$0.95 \le r \le 1.00$	Test for linearity (r^2)	3	3	$0.98 \le r^2 \le 1.00$
		0.75	$0.90 \le r < 0.95$			2.5	$0.95 \le r^2 < 0.98$
		0.5	$0.5 \le r < 0.90$			2	$0.93 \le r^2 < 0.95$
		0.25	$0.0 \le r < 0. 5$			1.5	$0.90 \le r^2 < 0.93$
		0	0			1	$0.80 \le r^2 < 0.90$
						0.5	$0.50 \le r^2 < 0.80$
						0.25	$0.0 \le r^2 < 0.50$
						0	0

Table 17. Points awarded for maintaining target altitude during Glide Slope. SSE mean is irrelevant while following the glide slope.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range	2.5	2.5	$80 \le GR \le 100$	"Fair" Range	1.5	1.5	$75 \le FR \le 100$
Percentage		2	$60 \le GR < 80$	Percentage		1	$50 \le FR < 75$
(GR)		1.5	$40 \le GR < 60$	(FR)		0.5	$25 \le FR < 50$
		1	$20 \le GR < 40$			0.25	$0 \le FR < 25$
		0.5	$0 < GR < 20$			0	0
		0	0				
SSE Target	2	2	< 25% * mean	SSE Mean	2	2	< 25% * mean
Airspeed		1.5	< 50% * mean	Airspeed		1.5	< 50% * mean
		1	< 75% * mean			1	< 75% * mean
		0.5	< 100% * mean			0.5	< 100% * mean
		0	> 100% * mean			0	> 100% * mean
Correlation	1	1	$0.75 \le r \le 1.00$	Test for	2	2	$0.75 \le r^2 \le 1.00$
between		0.75	$0.50 \le r < 0.75$	linearity (r^2)		1.5	$0.50 \le r^2 < 0.75$
Airspeed		0.5	$0.25 \le r < 0.50$			1	$0.25 \le r^2 < 0.50$
and target (r)		0.25	$0.0 \le r < 0.25$			0.5	$0.0 \le r^2 < 0.25$
		0	0			0	0

Table 18. Points awarded for maintaining target airspeed during Glide Slope.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range	3	3	$85 \le GR \le 100$	"Fair" Range	1.5	1.5	$75 \le FR \le 100$
Percentage		2.5	$70 \le GR < 85$	Percentage		1	$50 \le FR < 75$
(GR)		2	$55 \le GR < 70$	(FR)		0.5	$25 \le FR < 50$
		1.5	$40 \le GR < 55$			0.25	$0 \le FR < 25$
		1	$25 < GR < 40$			0	0
		0.5	$0 < GR < 25$				
		0	0				
SSE Target	2	2	< 25% * mean	SSE Mean	2	2	< 25% * mean
Heading		1.5	< 50% * mean	Heading		1.5	< 50% * mean
		1	< 75% * mean			1	< 75% * mean
		0.5	< 100% * mean			0.5	< 100% * mean
		0	> 100% * mean			0	> 100% * mean
Correlation	1	1	$0.75 \le r \le 1.00$	Test for	2	2	$0.75 \le r^2 \le 1.00$
between		0.75	$0.50 \le r < 0.75$	linearity (r^2)		1.5	$0.50 \le r^2 < 0.75$
Heading		0.5	$0.25 \le r < 0.50$			1	$0.25 \le r^2 < 0.50$
and target (r)		0.25	$0.0 \le r < 0.25$			0.5	$0.0 \le r^2 < 0.25$
		0	0			0	0

Table 19. Points awarded for maintaining target heading during Glide Slope.

Factor	Total Points	Points	Distribution	Factor	Total Points	Points	Distribution
"Good" Range	1.5	1.5	$75 \le GR \le 100$	"Fair" Range	1	1	$75 \le FR \le 100$
Percentage		1	$50 \le GR < 75$	Percentage		0.75	$50 \le FR < 75$
(GR)		0.5	$25 \le GR < 50$	(FR)		0.5	$25 \le FR < 50$
		0.25	$0 \le GR < 25$			0.25	$0 \le FR < 25$
		0	0			0	0
SSE Target	1.5	1.5	< 34% * mean	SSE Mean	2	2	< 25% * mean
Vertical		1	< 67% * mean	Vertical		1.5	< 50% * mean
Airspeed		0.5	< 100% * mean	Airspeed		1	< 75% * mean
		0	> 100% * mean			0.5	< 100% * mean
						0	> 100% * mean
Correlation	1	1	$0.75 \le r \le 1.00$	Test for	2	2	$0.75 \le r^2 \le 1.00$
between		0.75	$0.50 \le r < 0.75$	linearity (r^2)		1.5	$0.50 \le r^2 < 0.75$
Vertical		0.5	$0.25 \le r < 0.50$			1	$0.25 \le r^2 < 0.50$
Airspeed		0.25	$0.0 \le r < 0.25$			0.5	$0.0 \le r^2 < 0.25$
and target (r)		0	0			0	0

Table 20. Points awarded for maintaining target vertical airspeed during Glide Slope.

Segment	Parameter	"Good" Range Points	Distribution	"Fair" Range Points	Distribution
At Intercept	Altitude	1.5	1150 ≤ feet ≤ 1250	0.5	1125 ≤ feet ≤ 1275
	Airspeed	1.5	165 ≤ KCAS ≤ 175	0.5	160 ≤ KCAS ≤ 180
	Heading	1.5	89° ≤ Heading ≤ 91°	0.5	88° ≤ Heading ≤ 92°
	Vertical Airspeed	1.5	-75 ≤ FPM ≤ 75	0.5	-125 ≤ FPM ≤ 125
At Decision Point	Altitude	8	190 ≤ feet ≤ 210	4	185 ≤ feet ≤ 215
	Airspeed	4.5	170 ≥ KCAS ≤ 180	2	170 ≥ KCAS ≤ 185
	Heading	1.5	89° ≤ Heading ≤ 91°	0.5	88° ≤ Heading ≤ 92°
	Vertical Airspeed	3	-745 ≤ FPM ≤ -915	1.5	-660 ≤ FPM ≤ -1000
Minimum Altitude		4	≥ 150 feet	0	< 150 feet

Table 21. Points awarded while at the glide slope intercept, at the decision point and for the minimum altitude during wave off.

RESULTS:

G TURN ANALYSIS

Effects of Seat Position On The Ability to Maintain Constant Acceleration Turns:

The results from two sample unequal variance t tests indicated that the subject pool spent a statistically significant larger amount of time during the G turns in the Good and Fair ranges for all G levels while upright as compared to supine under static conditions (see Table 22). The SSE target for G levels were significantly lower for static low and high G turns while upright. However, no statistically significant differences in SSE target for G levels were found based on body position when comparing dynamic turns (see Table 23). Interactions between regressors found during ANCOVA tests are listed in Table 24. Fig 5. shows an example of the actual 11 G_{radial} vs the Ideal profile for Subject S1 while he was supine under dynamic conditions. Fig. 6 shows an example of the difference between the Ideal profile and Subject S1's +Gz performance during a dynamic upright +9 Gz turn.

Essentially no statistically significant differences were found referable to body position when comparing the ability to maintain airspeed during static G turns (see Table 25). When comparing dynamic performance, most of the significant differences occurred when comparing the low G turns (fewer errors occurred while upright). The SSE target airspeed values were significantly lower while subjects were supine during high G turns, however. Table 26 contains the dynamic mean airspeed values for the subject pool. Interactions between airspeed regressors found during ANCOVA tests are listed in Table 27.

As with airspeed performance during the G turns, there were essentially no statistically significant differences related to body position in the ability of the subjects to maintain a constant altitude. Regardless of position, it was equally difficult to hold a level 10,000 foot 360° turn. Tables 28 and 29 contain the subject means for altitude parameters during the G turns. Table 30 contains the interactions between altitude regressors found during ANCOVA tests.

UPRIGHT Static:	Low G	Medium G	High G	SUPINE Static:	Low G	Medium G	High G
SSE Target:	122.6 *	409.9	375.0 *	SSE Target:	593.7	3187.1	4836.1
Good % Range:	42.1 *	51.1 *	71.9 *	Good % Range:	24.7 **	24.1	16.1 **
Fair % Range:	59.6 *	70.5 *	88.5 *	Fair % Range:	34.3 **	37.2	31.5
Correlation (r):	0.40	0.48	0.49	Correlation (r):	0.37	0.38	0.63
SSE Mean:	99.1	190.1	94.8	SSE Mean:	231.4	1600.0	1102.4
r^2:	0.29	0.25	0.33	r^2:	0.23 **	0.32	0.52
Turn Total:	358.3°	356.5°	356.4°	Turn Total:	359.1°	360.9°	369.5°

Table 22. Mean G performance for subject pool during G turns for static data runs. Effects of body position on performance: *: statistically significant difference comparing upright vs supine during static runs ($p < 0.05$); **: statistically significant difference comparing upright vs supine during dynamic runs ($p < 0.05$).

UPRIGHT Dynamic:	Low G	Medium G	High G	SUPINE Dynamic:	Low G	Medium G	High G
SSE Target:	375.9 *	1643.1 *	5101.9 *	SSE Target:	865.7	2635.2	8767.6
GOOD % Range:	33.3	35.2 *	19.9 *	GOOD % Range:	16.6	27.1	8.0
FAIR % Range:	47.6 *	47.4 *	32.0 *	FAIR % Range:	25.4	36.2	25.3
Correlation (r):	0.35	0.48	0.50	Correlation (r):	0.47	0.43	0.60
SSE Mean:	185.2	508.6	1090.8 *	SSE Mean:	352.8	909.6	1791.7
r^2:	0.14 *	0.29	0.34	r^2:	0.30	0.24	0.46
Turn Total:	355.8°	357.8°	353.1°	Turn Total:	357.0°	360.9°	360.4°

Table 23. Mean G performance for subject pool during G turns for dynamic data runs. Effects of motion on performance: *: statistically significant difference comparing static vs dynamic upright runs ($p < 0.05$); there were no statistically significant differences found when comparing static vs dynamic supine runs.

Parameter	Interaction	F	p
SSE Target for G	G level and position	6.1	0.001
	experience and position	9.1	< 0.000
	position, G load and experience	3.6	0.001
Good G range	position and motion	11.9	0.001
	position, motion and G load	3.9	0.02
Fair G range	position and motion	19.8	< 0.000
	position , motion and G load	5.2	0.006
SSE Mean for G	position and G load	4.3	0.01
	position and experience	15.7	< 0.000
	position, G load and experience	4.7	< 0.000

Table 24. Interactions between regressors during analysis of the subjects' ability to maintain required G levels during the OSCAR pattern indicated by ANCOVA tests.

UPRIGHT Static:	Low G	Medium G	High G	SUPINE Static:	Low G	Medium G	High G
SSE Target:	986,242	1,648,491	846,423	SSE Target:	1,230,856	538,829	469,268 **
GOOD % Range:	36.3	11.5	20.4	GOOD % Range:	20.0 **	21.6	23.1
FAIR % Range:	58.4	21.4 *	40.7	FAIR % Range:	37.3 **	41.1	42.4
Correlation (r):	0.75	0.71	0.66	Correlation (r):	0.58 **	0.57 **	0.75
SSE Mean:	232,566	237,267	99,610	SSE Mean:	228,239	185,013	137,072
r^2:	0.70	0.64	0.59	r^2:	0.46 **	0.40 **	0.70

Table 25. Mean airspeed performance for subject pool during G turns for static data runs. Effects of body position on performance: *: statistically significant difference comparing upright vs supine during static runs ($p < 0.05$); **: statistically significant difference comparing upright vs supine during dynamic runs ($p < 0.05$).

UPRIGHT Dynamic:	Low G	Medium G	High G	SUPINE Dynamic:	Low G	Medium G	High G
SSE Target:	1,380,334	2,132,812	1,836,348	SSE Target:	1,519,039	4,152,246 **	853,150
GOOD Range:	28.4	17.4	19.6	GOOD Range:	18.0	21.3	18.5
FAIR Range:	51.7	32.2	36.6	FAIR Range:	32.0	41.9	39.7
Correlation (r):	0.78	0.75	0.71	Correlation (r):	0.59	0.61	0.68
SSE Mean:	430,747	578,465 *	544,813 *	SSE Mean:	469,879	302,702	289,994
r^2:	0.64	0.68	0.65	r^2:	0.43	0.39	0.56

Table 26. Mean airspeed performance for subject pool during G turns for dynamic data runs. Effects of motion on performance: *: statistically significant difference comparing static vs dynamic upright runs ($p < 0.05$); **: statistically significant difference comparing static vs dynamic supine runs ($p < 0.05$).

Parameter	Interaction	F	p
Fair Airspeed range	G level and position	3.7	0.03
SSE Mean for Airspeed	position and experience	3.5	0.01
r	position, G load and experience	3.8	0.0004
r^2	position, G load and experience	2.6	0.01

Table 27. Interactions between ANCOVA regressors found during analysis of airspeed parameters during performance of G turns.

UPRIGHT Static:	Low G	Medium G	High G	SUPINE Static:	Low G	Medium G	High G
SSE Target:	139,325,721	145,490,658	294,593,64	SSE Target:	41,575,667	455,084,77 8	85,187,205
GOOD % Range:	32.8	22.3	19.9	GOOD % Range:	33.3	11.1	25.9
FAIR % Range:	64.9	46.5	48.9	FAIR % Range:	61.8	29.5	61.5
Correlation (r):	0.75	0.78	0.73	Correlation (r):	0.70	0.87	0.79
SSE Mean:	17,401,494	49,880,215	76,361,439	SSE Mean:	4,834,601	90,215,994	30,303,530 *
r^2:	0.70	0.74	0.69	r^2:	0.50	0.80	0.66

Table 28. Mean altitude performance for subject pool during G turns for static data runs. Effects of body position on performance: There were no statistically significant differences comparing upright vs supine during static runs. *: statistically significant difference comparing upright vs supine during dynamic runs ($p < 0.05$).

UPRIGHT Dynamic:	Low G	Medium G	High G	SUPINE Dynamic:	Low G	Medium G	High G
SSE Target:	154,192,029	2,076,619,068	640,573,118	SSE Target:	198,962,936 **	3,536,183,939 **	332,204,441 **
GOOD % Range:	33.5	9.4	12.2	GOOD % Range:	21.0	6.8	9.1 **
FAIR % Range:	63.8	23.1	28.2	FAIR % Range:	49.6	18.5	28.2 **
Correlation (r):	0.71	0.74	0.74	Correlation (r):	0.66	0.82	0.78
SSE Mean:	24,282,971	113,211,567	236,641,870 *	SSE Mean:	30,244,067 **	420,736,788	79,018,687
r^2:	0.59	0.75	0.67	r^2:	0.54	0.74	0.70

Table 29. Mean altitude performance for subject pool during G turns for dynamic data runs. Effects of motion on performance: *: statistically significant difference comparing static vs dynamic upright runs ($p < 0.05$); **: statistically significant difference comparing static vs dynamic supine runs ($p < 0.05$).

Parameter	Interaction	F	p
Good Altitude range	G level, motion and position	3.6	0.03
	G level, motion, position and experience	2.4	0.02
SSE Mean for Altitude	position, G load	6.1	0.003
r	position, G load and experience	2.1	0.04

Table 30. Interactions between ANCOVA regressors found during analysis of altitude parameters during performance of G turns.

Effects of Motion On The Ability to Maintain Constant Acceleration Turns:

As seen in Table 23, motion effects did not lead to differences in G parameters when subjects were supinated, whereas there were statistically significant differences when upright. SSE target for G levels were lower for static as compared to dynamic conditions for all loads, and a greater percentage of the turn was spent in the Good and Fair ranges when static for all G levels (except Good low G turns, $p = 0.1$). The source of these differences was indicated based on ANCOVA results which showed that there was an interaction between motion and G load for SSE target and SSE mean values ($F = 4.5$, $p = 0.01$; $F = 3.4$, $p = 0.03$, respectively). Interactions were indicated for the percentage of time spent in Good and Fair ranges for motion and position ($F = 11.9$, $p = 0.001$; $F = 19.8$, $p < 0.000$, respectively), motion and G load ($F = 8.1$, $p = 0.0004$; $F = 5.0$, $p = 0.008$, respectively) and motion, position and G load ($F = 3.9$, $p = 0.02$; $F = 5.2$, $p = 0.006$, respectively).

Fisher's Least Square Difference (LSD) test indicated that the source of differences based on the main ANCOVA factor G level for SSE for G target loads, percentage spent in the

Good G range, correlation factor for G and r^2 for G were due to differences between low and medium G loads as compared to high G levels. Differences in percentage of time spent in the Fair range were due only to differences between low and medium G loads. For SSE Mean values, the LSD test indicated that for this controllability factor each G level was different from each of the other levels.

Table 26 indicated that there were few motion based differences in the ability to maintain required airspeed during the G turns. There were the following statistically significant interactions indicated by ANCOVA results: for Good and Fair airspeed range, there was an interaction between motion and flight experience ($F = 4.1$, $p = 0.003$; $F = 3.1$, $p = 0.02$, respectively) and there was an interaction between motion, G load and experience for r ($F = 2.1$, $p = 0.04$).

LSD test results indicated that when looking at airspeed values, the source of differences based on the main factor G level for SSE target were due to differences between low and medium G loads as compared to high G levels. For the percentage spent in the Good and Fair airspeed range, the differences were due to the relation between low and medium G levels.

Motion based significant differences in the ability to maintain altitude were primarily found only when subjects were supine (see Table 29) in that they had a significantly harder time (based on SSE target) under dynamic conditions. There were statistically significant interactions between motion and G level for SSE for target altitude ($F = 3.1$, $p = 0.05$), between motion and flight experience for the percentage of the turn spent in the Good and Fair range ($F = 10.8$, $p < 0.000$; $F = 5.6$, $p = 0.003$, respectively) and for motion, G level and experience ($F = 2.2$, $p = 0.03$) and for motion, position, G level and experience for the time spent in the Good altitude range ($F = 2.4$, $p = 0.02$).

Effects of Onset/Offset Rate on Flight Performance

There were no differences in onset parameters due to motion effects when supinated. Upright dynamic onset rates were lower than when flying statically. There were no differences referable to body position during static turns. Supine onset rates were statistically significantly slower than when upright for low and medium G turns. No significant differences in altitude were noted. When compared to the "ideal" onset profile, onset rates, heading changes and roll rates were typically faster than the ideal. The range in roll values were similar (± 16%) as were altitude levels (± 6%), however based on the rate of change in altitude (feet/s), it was harder to keep the airplane at a level altitude during onset than under ideal conditions. While there were few differences based on seating position or motion on offset rates, actual values were much faster than predicted by the ideal model, which assumed symmetric onset and offset profiles. Roll rates and ranges were faster and larger for static as compared to dynamic upright conditions. Dynamic roll rates and ranges were significantly faster and larger when supine as compared to upright for low and high +Gz turns. See Table 31 for mean and ideal onset values.

There were motion related differences when subjects unloaded from the G turns. Under dynamic conditions when upright, offsets were faster (low and medium G), the overall roll angle

was smaller (all G levels) and the roll rate was shorter (low G). When subjects were supinated, offsets were quicker when flying dynamically ($p < 0.05$ only during medium G turns). There were few body position related differences when comparing upright to supine performance during static turns. When dynamic, the extent of the roll angle and rate of change of the roll angle were significantly different between the two body positions during low and high G turns. See Table 32 for mean values.

G Turn Performance Grades

Based on the grading scheme, the following observations can be made (Table 33). Subjects with the most piloting flight hours (S1, S2, S3 and S4) performed somewhat better upright than supinated (based on position and regardless of motion effects, S2 flew significantly better upright). The naive subject (S5), also based on position alone, flew significantly better supinated, while the performance of subjects S6 and S7 was mixed. If one calculated the percentage of total possible points earned for each parameter, there were no statistical differences based on seating position.

See Appendix A for the raw data for the G turns, including G level, airspeed, altitude and heading.

Effects of Fatigue on Performance

To determine if fatigue was a factor in effecting the ability to maintain a constant acceleration level turns under dynamic conditions, SSE from target +Gz and the "Good" and "Fair" range scores for the first turn set was compared to the second set. Based on ANCOVA results using position, G level and whether the turn was first or second as the main factors and confirmed using Fisher's LSD test, there were no statistically significant differences due to fatigue demonstrated at the $p < 0.05$ level.

	UPRIGHT Static			UPRIGHT Dynamic		
PARAMETER	Low G	Medium G	High G	Low G	Medium G	High G
Time (s)	6.1	6.3	5.5	5.6	5.9	5.5
Onset Rate (G/s)	0.87 *	0.94	1.58 *	0.63	0.86	1.01
Heading Change (°)	32.2	38.1	39.6	24.4	31.7	32.0
Heading Rate (°/s)	5.4 *	4.9	6.6	4.2	4.9	7.3
Roll Range (°)	74.2 *	68.1 *	81.9	66.0	78.4	76.1
Roll Rate (°/s)	14.0	14.3	14.8	13.7	17.0	18.6
Max Altitude (ft)	10107	9892	9851	10077	10117	9725
Min Altitude (ft)	10014	9767	9808	9964	9966	9599
Altitude Rate of Change (ft/s)	11.5	19.4	22.1	17.2	21.8	20.1
	SUPINE Static			SUPINE Dynamic		
Time (s)	6.5	6.4	6.6	6.1	6.3	6.2
Onset Rate (G/s)	0.97	1.17	1.23	0.96 ++	1.20 ++	1.44
Heading Change (°)	43.9	42.6	51.6	38.1 ++	41.7	40.4
Heading Rate (°/s)	6.7	5.9	7.4	6.5 ++	6.2 ++	5.9
Roll Range (°)	78.6	80.9 +	77.0	75.0 ++	83.2 ++	77.3
Roll Rate (°/s)	14.3	19.6	12.0	15.9	19.4	18.5
Max Altitude (ft)	10139	10021	9927	10126	10028	9623
Min Altitude (ft)	10024	9844	9745	9971	9778	9357
Altitude Rate of Change (ft/s)	17.1	23.8 **	26.3	24.7	40.5 ++	36.7 ++
	IDEAL					
Time (s)	6.5	5.7	5.1			
Onset Rate (G/s)	0.50	1.00	1.20			
Heading Change (°)	58.3	68.5	77.8			
Heading Rate (°/s)	9.4	12.8	16.0			
Roll Range (°)	78.1	81.3	85.2			
Roll Rate (°/s)	5.5	7.4	9.2			
Max Altitude (ft)	10017	10011	10052			
Min Altitude (ft)	9998	9977	9992			
Altitude Rate of Change (ft/s)	1.1	4.9	1.1			

Table 31. Ideal and mean values during onset into the G turns. Effects of motion: *: significant difference between static vs dynamic upright values ($p < 0.05$); **: significant difference between static vs dynamic supine values. Effects of body position: +: significant difference between upright vs supine static values; ++: significant difference between upright vs supine dynamic values.

	UPRIGHT Static			UPRIGHT Dynamic		
PARAMETER	Low G	Medium G	High G	Low G	Medium G	High G
Time (s)	4.1 *	3.7 *	3.9	2.6	2.6	2.4
Offset Rate (G/s)	1.36	1.66	2.81	1.45	2.14	3.11
Heading Change (°)	15.9	13.3	20.4	9.0	7.1	6.2
Heading Rate (°/s)	3.4	2.9	4.3	3.1	2.6	2.5
Roll Range (°)	66.6 *	65.4 *	67.0 *	22.9	33.7	28.7
Roll Rate (°/s)	21.7 *	22.1	24.9	7.9	13.4	13.7
Max Altitude (ft)	9961	9561	9026	9875	9367	8526
Min Altitude (ft)	9823	9425	8817	9801	9140	8279
Altitude Rate of Change (ft/s)	27.8	39.0	77.1	23.4	77.4	122.0
	SUPINE Static			SUPINE Dynamic		
Time (s)	3.3	3.3 **	2.8	3.0	2.4	2.7
Offset Rate (G/s)	1.65	2.46	2.94	1.75 ++	2.86	2.85
Heading Change (°)	9.9	8.0	7.2	8.0	7.3	7.1
Heading Rate (°/s)	2.4	1.9 **	2.4	2.8	3.2	2.5
Roll Range (°)	65.2 **	67.3 **	63.1	48.0 ++	43.5	52.8 ++
Roll Rate (°/s)	24.7 **	25.6	25.5	16.8 ++	11.7	22.5 ++
Max Altitude (ft)	9876	8553 +	9791	9920	8415 ++	9004
Min Altitude (ft)	9774	8401 +	9574	9774	8192 ++	9186
Altitude Rate of Change (ft/s)	31.5	39.4 **	78.9	41.0	88.5	79.1

Table 32. Mean values during offset from the G turns. Effects of motion: *: significant difference ($p < 0.05$) between static vs dynamic upright values; **: significant difference between static vs dynamic supine values. Effects of body position: +: significant difference between upright vs supine static values; ++: significant difference between upright vs supine dynamic values.

Subject	Position	Motion	Score	Grade	Experience
S1	Upright	Static	78.3	Average	F/A 18 instructor pilot, 2600 hrs tactical jets, A-4,
		Dynamic	74.7	Fair	A-6, F-14
	Supine	Static	70.7	Fair	
		Dynamic	66.8	Fair	
S2	Upright	Static	75.7	Average	3900 hrs, 50:50 fixed and rotary wing including P-3,
		Dynamic	65.1	Fair	F-18, A-4, T-34, T-28
	Supine	Static	57.0	Poor	
		Dynamic	58.5	Poor	
S3	Upright	Static	73.3	Fair	1600 hrs P-3, 100 hrs T-44, 80 hrs T-34
		Dynamic	71.5	Fair	
	Supine	Static	70.7	Fair	
		Dynamic	64.3	Poor	
S4	Upright	Static	65.0	Fair	750 hrs A-6E, 100 hrs T-2, T-34, F-18, Citation
		Dynamic	59.0	Poor	
	Supine	Static	60.8	Poor	
		Dynamic	45.3	Poor	
S5	Upright	Static	54.2	Poor	None
		Dynamic	62.2	Poor	
	Supine	Static	66.2	Fair	
		Dynamic	67.3	Fair	
S6	Upright	Static	70.8	Fair	1000 hrs S-3 NFO, 50 hrs as pilot, Cessna 182
		Dynamic	46.3	Poor	private pilot VFR rating
	Supine	Static	60.8	Poor	
		Dynamic	67.7	Fair	
S7	Upright	Static	50.3	Poor	25 hrs Cessna 150 and Piper Warrior
		Dynamic	68.0	Fair	
	Supine	Static	66.8	Fair	
		Dynamic	67.3	Fair	

Table 33. Piloting performance grades during G turns for subject population.

ILS LANDING TASK ANALYSIS

Based on ANCOVA results and Fisher's LSD post hoc tests, there were few statistically significant differences in flight performance during the all four phases of the landing procedure (approach, glide slope intercept, following the glide slope and the decision point) referable on body position or effects of motion. Results from t test analyses confirmed that there were no body position related differences during dynamic runs. The few isolated significant differences are listed in Tables 34 (ILS approach), 35 (glide slope) and 36 (at glide slope intercept and the decision point) along with the group flight parameter means. Table 37 contains the grades earned during the ILS task. No significant differences related to body position or motion were found for performance grades. Fig. 7 shows an example of the actual landing vs the Ideal profile for Subject S1 while he was supine under dynamic conditions. Fig. 8 shows an example of the

difference between the Ideal profile and Subject S1's performance during a dynamic upright landing.

These are the few differences detected during ANCOVA analyses (see Table 38 for a listing of all indicated interactions). During the ILS approach, motion was related to changes in the percentage spent in the Good altitude range ($F = 4.7$, $p = 0.03$). ANCOVA results indicated that there were statistically significant differences based on flight experience for almost all of the ILS approach parameters (except altitude r^2, heading r and r^2, percentage of vertical climb in the Fair range, SSE target and SSE mean for the vertical airspeed).

As the subjects followed the glide slope towards the decision point, ANCOVA results indicated that flight experience was related to differences in percentage of time spent in Good and Fair airspeed ranges ($F = 2.9$, $p = 0.03$; $F = 3.8$, $p = 0.01$, respectively). Differences in the ability to maintain target heading could also be attributed to flight experience for differences in percentage of time spent in Good and Fair ranges, r value, SSE mean and r^2 ($F = 8.1$, $p < 0.000$; $F = 4.0$, $p = 0.01$; $F = 3.0$, $p = 0.02$; $F = 3.8$, $p = 0.01$; $F = 5.5$, $p = 0.001$, respectively). Flight experience was related to differences in percentage of time spent in Good and Fair vertical airspeed ranges, as well r^2 ($F = 6.9$, $p = 0.0001$; $F = 10.6$, $p < 0.000$; $F = 3.1$, $p = 0.02$; $F = 3.8$, respectively).

Few statistical differences could be attributed to fatigue during the dynamic ILS tasks as well. Fatigue was a factor while the subjects followed the glide slope towards the decision point for r^2 and the correlation factor between actual and target heading ($F = 4.3$, $p = 0.04$; $F = 4.5$, $p = 0.05$, respectively). Interactions between fatigue and body positions were found for percentage of time spent in the Fair airspeed range and heading r^2 ($F = 4.2$, $p = 0.05$; $F = 4.4$, $p = 0.04$, respectively).

See Appendix B for the raw data for the ILS task, including airspeed, altitude, heading and vertical airspeed (climb rate).

QUESTIONNAIRE RESULTS

Non-parametric statistical tests (chi square and Wilcoxon Matched Pairs) were performed on the questionnaire responses. The only significant difference was a slightly greater amount of left arm discomfort in the supine configuration. Summary results are given in Tables 39 and 40. Questions #1 to #7 rated physical comfort, #8 determined if there was sufficient seat padding, #9 dealt with restraint, #10 to #14 determined if anti-G suit inflation was hindered, #15 to #18 determined if vision was impaired, #21 to #25 determined reach impairments, #27 to #35 included a self assessment of flight performance, #37 asked if the simulation had sufficient airplane handling qualities and #38 asked if the subjects felt that they had sufficient training. The balance of the questions were essays and were not included in the statistical analysis.

Condition	Parameter	Good Range	Fair Range	r	SSE Target	SSE Mean	r²
Upright	Altitude	81.5	91.4	0.54	989,615	304,577	0.43
Static	Airspeed	85.1	98.1	0.49	13,387	8,574	0.34
	Heading	86.8	95.7	0.41	965	815	0.25
	Climb Rate	49.6	66.8	0.32	15,480,899 *	13,724,566 *	0.15
Upright	Altitude	87.7	95.7	0.61	1,401,910	516,685	0.48
Dynamic	Airspeed	90.5	98.7	0.49	16,945	11,459	0.35
	Heading	82.5	95.1	0.43	1,046	873	0.26
	Climb Rate	61.1	74.2	0.26	98,481,798	95,853,880	0.12
Supine	Altitude	80.8	91.7	0.64	2,176,728	830,240	0.50
Static	Airspeed	88.1	95.9	0.57	20,871	10,264	0.44
	Heading	75.3	92.4	0.42	2,407	2,114	0.21
	Climb Rate	53.1	68.4	0.35	103,595,213	100,094,657	0.19
Supine	Altitude	94.8	96.7	0.64	826,082	265,801	0.48
Dynamic	Airspeed	90.8	98.2	0.55	14,121	9,330	0.41
	Heading	80.7	95.8	0.44	908	741	0.24
	Climb Rate	62.7	75.7	0.24	104,306,250	102,991,639	0.10

Table 34. Mean subject pool flight parameters during ILS approach. *: statistically significant difference ($p < 0.05$) between static vs dynamic for upright position.

Condition	Parameter	Good Range	Fair Range	r	SSE Target	SSE Mean	r^2
Upright	Altitude	18.7	29.2	0.998	3,645,043 *	N/A	0.996
Static	Airspeed	65.3	68.8	0.49 +	18,288	7,766 * +	0.33
	Heading	92.7	98.1	0.42	482	324	0.22
	Climb Rate	28.1	50.5	0.25	81,319,915 +	74,281,975 +	0.08
Upright	Altitude	17.9	26.1	0.996	7,272,150	N/A	0.99
Dynamic	Airspeed	56.4	61.8	0.46	93,855	58,961	0.31
	Heading	90.9	97.4	0.38	1,208	998	0.20
	Climb Rate	22.5	45.6	0.15	405,372,775	395,000,868	0.05
Supine	Altitude	18.8	27.9	0.995	12,453,147	N/A	0.99
Static	Airspeed	55.5	61.7	0.71 **	54,671	24,791	0.51 **
	Heading	78.5	93.0	0.40	2,964	1,092	0.24
	Climb Rate	24.1	48.9	0.23	225,318,570	204,750,503	0.09
Supine	Altitude	21.4	30.3	0.997	6,120,242	N/A	0.995
Dynamic	Airspeed	55.2	59.5	0.48	29,297	21,747	0.31
	Heading	83.6	96.3	0.32	985	750	0.17
	Climb Rate	25.3	50.9	0.16	209,736,719	200,559,844	0.06

Table 35. Mean subject pool flight parameters while following the glide slope towards the decision point. Motion effects: *: statistically significant difference ($p < 0.05$) between static vs dynamic for upright position, ** for supine position; Position effects: +: significant difference between upright and supine under static conditions.

Condition	Altitude (ft)	Airspeed (KCAS)	Heading (°)	Vertical Airspeed (FPM)	Minimum Altitude (ft)
AT INTERCEPT					
Upright Static	1199.4	171.0	90.2	-106.2	
Upright Dynamic	1199.6	171.7	90.3	-88.2	
Supine Static	1190.2	171.3	90.0	-44.9	
Supine Dynamic	1199.3	170.9	89.9	-80.0	
DECISION POINT					
Upright Static	179.7	169.7	90.3	-912.6	
Upright Dynamic	178.1	174.0	90.0	-912.8	
Supine Static	179.3	170.4	90.0	-931.0	
Supine Dynamic	176.0	169.0	89.6	-901.1	
WAVE OFF					
Upright Static					155.1
Upright Dynamic					144.2
Supine Static					153.7
Supine Dynamic					159.4

Table 36. Mean flight parameters at the intercept with the glide slope (ideal: 1200 ft, 170 KCAS, 90° heading, 0 FPM), at the decision point to wave off (ideal: 200 ft, 170 KCAS, 90° heading,
-830 FPM) and the minimum altitude during the wave off (ideal: ≥ 150 ft). There were no statistically significant differences between any parameter.

Subject	Position	Motion	Score	Grade
S1	Upright	Static	68.8	Fair
		Dynamic	55.8	Poor
	Supine	Static	75.8	Average
		Dynamic	70.4	Fair
S2	Upright	Static	67.8	Fair
		Dynamic	67.8	Fair
	Supine	Static	66.8	Fair
		Dynamic	57.5	Poor
S3	Upright	Static	76.3	Average
		Dynamic	72.0	Fair
	Supine	Static	69.0	Fair
		Dynamic	68.0	Fair
S4	Upright	Static	68.8	Fair
		Dynamic	67.3	Fair
	Supine	Static	59.5	Poor
		Dynamic	63.8	Poor
S5	Upright	Static	70.4	Fair
		Dynamic	73.3	Fair
	Supine	Static	65.5	Fair
		Dynamic	64.4	Poor
S6	Upright	Static	78.3	Average
		Dynamic	74.1	Fair
	Supine	Static	83.8	Good
		Dynamic	84.1	Good
S7	Upright	Static	47.8	Poor
		Dynamic	47.0	Poor
	Supine	Static	51.3	Poor
		Dynamic	46.4	Poor

Table 37. Flight performance scores for the ILS task.

ILS Segment	Parameter	Interaction	F	p
ILS Approach	SSE Mean for Altitude	motion and position	5.0	0.03
	SSE Target for Heading	motion and experience	2.5	0.05
	SSE Mean for Heading	motion and experience	3.7	0.01
	r^2 for Heading	motion and experience	5.1	0.001
	r for Vertical Airspeed	motion, position and experience	3.0	0.02
Glide Slope	Fair Altitude Range	position and experience	3.4	0.01
	Good Airspeed Range	position and experience	3.8	0.01
	Fair Airspeed Range	position and experience	2.8	0.03
	SSE Target for Airspeed	motion and position	4.3	0.04
	r^2 for Heading	motion, position and experience	2.7	0.04

Table 38. Interactions between regressors during analysis of the subjects' ability to maintain required flight parameters during the ILS task indicated by ANCOVA tests.

Question #	Question	Mean ± 1 S.D.	Meaning
1	Right arm Stick	2.3 ± 1.4	Slight to moderate discomfort
2	Left arm Throttle	1.5 ± 1.2	Slight to somewhat moderate discomfort
3	Head	1.3 ± 1.3	Slight to somewhat moderate discomfort
4	Neck	1.3 ± 1.0	Slight to somewhat moderate discomfort
5	Chest	0.7 ± 1.1	Slight discomfort
6	Abdomen	0.5 ± 0.8	Slight discomfort
7	Legs	0.9 ± 1.2	Slight discomfort
8	Padding: head	1.2 ± 0.4	Sufficient padding for head
	Padding: up back	1.2 ± 0.4	Sufficient padding for upper back
	Padding: low back	1.4 ± 0.5	Sufficient padding for lower back
	Padding: seat pan	1.2 ± 0.4	Sufficient padding for buttocks
9	Harness restraint	4.2 ± 0.9	Average to excellent restraint
10	anti-g suit calves	4.8 ± 0.6	Unimpeded calf bladder inflation
11	anti-g suit thighs	4.9 ± 0.3	Unimpeded thigh bladder inflation
12	anti-g suit abdomen	4.9 ± 0.3	Unimpeded abdomen bladder inflation
14	anti-g suit hose kink?	2.0 ± 0.0	anti-g suit hose did not kink
15	Vision: HUD	4.8 ± 0.4	Clear view of HUD
16	Vision: Left TV	4.5 ± 0.8	Mostly clear view of Left monitor
17	Vision: Center TV	4.8 ± 0.4	Clear view of Center monitor
18	Vision: Right TV	4.6 ± 0.7	Mostly clear view of Right monitor
21	Reach Throttle	3.8 ± 0.9	Average ability to reach throttle
22	Reach Throttle switches	4.7 ± 0.8	Better than average ability to reach throttle switches
23	Reach Stick	3.6 ± 1.1	Average ability to reach stick
24	Reach Stick switches	4.5 ± 0.9	Better than average ability to reach stick switches
25	Reach rudders	4.5 ± 1.1	Better than average ability to reach rudder pedals
27	Fly S-2	4.1 ± 0.8	Better than average ability to fly S-2
31	Fly Oscar	2.9 ± 1.0	Average ability to fly high G turns
33	Fly Half Cuban Eight	3.7 ± 0.6	Somewhat better than average ability to fly Half Cuban Eight
35	Fly ILS	4.5 ± 0.7	Better than average ability to land
37	"Airplane-like ?"	3.6 ± 0.8	Flight characteristics greater than somewhat like real aircraft
38	Sufficient Training?	4.1 ± 1.0	Static training fairly well prepared subjects to fly DFS

Table 39. Mean upright questionnaire responses.

Question #	Question	Mean ± 1 S.D.	Meaning
1	Right arm Stick	1.7 ± 1.5	Slight to somewhat moderate discomfort
2	Left arm Throttle	2.4 ± 1.8	Slight to moderate discomfort
3	Head	0.4 ± 0.6	Slight discomfort
4	Neck	1.0 ± 1.2	Slight to somewhat uncomfortable
5	Chest	0.7 ± 0.9	Slight to somewhat uncomfortable
6	Abdomen	1.1 ± 1.0	Slight to somewhat uncomfortable
7	Legs	0.4 ± 0.6	Slight discomfort
8	Padding: head	1.5 ± 0.5	Insufficient padding for head
	Padding: upper back	1.5 ± 0.5	Insufficient padding for upper back
	Padding: lower back	1.5 ± 0.5	Insufficient padding for lower back
	Padding: seat pan	1.1 ± 0.4	Sufficient padding for buttocks
9	Harness restraint	4.4 ± 0.8	Better than average to excellent restraint
10	anti-g suit calves	4.9 ± 0.3	Unimpeded calf bladder inflation
11	anti-g suit thighs	5.0 ± 0.0	Unimpeded thigh bladder inflation
12	anti-g suit abdomen	4.7 ± 0.6	Unimpeded abdomen bladder inflation
14	anti-g suit hose kink?	2.0 ± 0.0	anti-g suit hose did not kink
15	Vision: HUD	4.3 ± 0.9	Mostly clear view of HUD
16	Vision: Left TV	4.6 ± 0.6	Mostly clear view of Left monitor
17	Vision: Center TV	4.6 ± 0.6	Mostly clear view of Center monitor
18	Vision: Right TV	4.6 ± 0.6	Mostly clear view of Right monitor
21	Reach Throttle	3.5 ± 1.5	Average ability to reach throttle
22	Reach Throttle switches	4.0 ± 1.1	Better than average ability to reach throttle switches
23	Reach Stick	4.3 ± 1.1	Better than average ability to reach stick
24	Reach Stick switches	4.4 ± 0.9	Better than average ability to reach stick switches
25	Reach rudders	4.1 ± 1.1	Better than average ability to reach rudder pedals
28	Fly S-2 Supine	4.1 ± 0.9	Better than average ability to fly S-2
32	Fly Oscar Supine	3.9 ± 0.9	Somewhat better than average ability to fly high G turns
34	Fly Half Cuban Eight Supine	3.8 ± 0.7	Somewhat better than average ability to fly Half Cuban Eight
36	Fly ILS Supine	4.1 ± 0.9	Better than average ability to land
37	"Airplane-like ?"	3.3 ± 0.9	Flight characteristics somewhat like real aircraft
38	Sufficient Training?	3.9 ± 0.6	Static training fairly well prepared subjects to fly DFS

Table 40. Mean supine questionnaire responses.

Subjective Assessment of Respiratory Effort

No statistically significant differences were found based on the subject's subjective assessment of their respiratory effort for either body position using the modified ten point Borg

Scale (Table 5). Very very slight respiratory effort was reported for the two basic maneuvers, the ILS task and the Vertical S-2. Slight to moderate effort was required for the Half Cuban Eight; the mean upright responses were slightly higher than the supine (3.0 vs 2.4, respectively). Moderate to somewhat strong effort was required during the low G turns (upright: 3.3, supine: 3.5), strong effort was reported for the medium G turns (upright: 5.3, supine: 5.5) and during high G turns a very strong effort was required (upright: 7.2, supine: 6.2).

Human Factors Results

There was some concern during the planning of this project that Coriolis effects may lead to stomach awareness during dynamic supine exposures. In fact, subjects were given training in how to vomit while supine without the need to sit up. None of the subject pool experienced any such effects.

During the structural tests of the supine cockpit installation prior to manned operations, the cockpit was subjected to 1.5 times the maximum G exposures allowed for the subjects. It was found that the seat design required alterations in the lower front support structure to withstand high -Gx loads. Modifications were made and tested prior to human exposures. Note that this result would not have been found with a standard (i.e. non-acceleration) flight simulator.

It was noted that under dynamic supine conditions it was harder to read the HUD symbology, particularly the smaller characters. Note that the visual displays were identical for both seating conditions. This was probably due to two effects. There were vision decrements based on increasing G load as anticipated, both peripheral light loss and graying effects, which reduced visibility. A second effect due to motion translation through the seat to the head box/helmet occurred which was not predicted. When supine, the helmet rested in the head box and despite additional padding (which helped) the motion tended to hinder the ability to focus on the HUD. This effect was more pronounced for some subjects as compared to others. Once this was noted, one of the project investigators told all of the subjects their current G level during the medium and high G turns.

There were many incidences of arm and elbow pain associated with both right (stick) and left (throttle) arms, though the extent varied with each cockpit. These problems, typically due to inadequate arm support, only developed under acceleration stress. A possible explanation for the cause of right arm discomfort using the side arm stick while upright was due to having an F-18 style stick with a F-16 style armrest.

One of the subjects (S2) was a very tall individual (77") who complained of inadequate neck and upper back support during the two types of acceleration maneuvers: G turns and Half Cuban Eight. This occurred because the adjustable upper back support in the supine cockpit could not accommodate such an individual. This problem was solved by providing additional padding. Note again that identification of this problem was only possible using a simulator with acceleration capabilities.

Loss of Consciousness

The primary purpose of flying supine is to increase G tolerance, which in turn should reduce the chance of G induced loss of consciousness (G-LOC). One subject (S2) did experience a G-LOC followed by an almost LOC event (A-LOC: a manifestation of symptoms of neurologic deficit without losing consciousness) while supinated during the high G turn. During the G-LOC, he reported that he was dreaming about flying the DFS during this project. He stated that it seemed like he experienced a "seamless transition from doing to dreaming to doing" again. During the A-LOC, Subject S2 reported a loss of voluntary upper body muscular control and admitted to confusion as to why he was unable to control the simulation. As it turns out, he was totally unaware that his legs were involuntarily convulsing which led to spurious rudder inputs. Fig. 9 shows the acceleration trace, longitudinal (fore and aft) and lateral (right and left) control stick movements and the rudder pedal inputs during Subject S2's +11 Gz supine turn prior to the G-LOC and A-LOC incidents. Clearly, he was able to hold the stick in the full aft position and applied fairly uniform rudder inputs. When this trace is compared to the A-LOC in Fig. 10, a decidedly different pattern emerges. After about 16.8 s, his rudder pedal inputs fluctuated along oscillating lateral stick movements. At about 18.5 s, the video tape shows convulsive shaking in his upper arm which lasted until about 22.8 s into the turn. Also at this point, his rudder inputs returned to the smoother pattern seen in the beginning of the turn. Fig. 10 also shows the event marker. Note that it was depressed repeatedly (as depicted by a positive slope) which may indicate a lack of control of the right (control stick) hand. These events may have been due to a lack of oxygen during a breath hold. While supinated, the +Gz vector is aimed through the chest and subjects did report increased breathing difficulty while supine.

CONCLUSIONS

The primary purpose of flying supine is to increase in +Gz tolerance. When these subjects were supinated, the effects of motion did not lead to significant differences in the ability to maintain specified G-loads, whereas there were significant differences when upright. Subjects demonstrated a lower error rate while flying statically as compared to dynamically for all loads. Motion effects led to few statistical differences in the ability to maintain airspeed. Only when comparing static to dynamic supine runs were significant differences in altitude demonstrated.

When analyzing seat position effects, subjects demonstrated fewer errors during the high-G turns while flying upright as compared to supine (statistically significantly different only when comparing static conditions). During dynamic turns, there were no significant differences in the performance error between actual and required G-level, although while subjects were upright they were able to maintain a higher percentage of the G turns within defined acceptable ranges. There were few differences based on seating position in the ability to maintain required airspeed under dynamic conditions and no statistical differences in maintaining altitude whether flying statically or dynamically.

In general, for the all subjects, ANCOVA results indicated there was a significant interaction between seating position and motion and an interaction between motion and G-load in the subject's ability to maintain G-levels within acceptable ranges.

One might suggest that fatigue was a factor in determining the ability to maintain a constant acceleration level turn. When comparing error rates while flying dynamically between the first set of turns performed during the first 20 min of the syllabus and the last set about 20 min later, no statistically significant differences were found.

A operationally significant parameter affecting G-tolerance is G onset rate. No differences in onset parameters due to motion effects were demonstrated when supinated, although upright dynamic onset rates were higher than while static. Supine onset rates were statistically significantly slower than when upright for low and medium +Gz turns.

Based on the piloting grading scheme, it was found that subjects with the most flight hours performed somewhat better upright than supinated. The naive subject flew significantly better supine. Overall, based the percentage of total possible points earned for each parameter, there were no statistical differences based on seating position (~4%).

The literature indicates that flying supinated reduces the chance of G-LOC. This investigation has shown that it is indeed possible to develop G-induced neurologic deficits which can effect flying performance with or without the subject being aware while it is happening to him. These events may have been due to a lack of oxygen caused by the increasingly difficult effort required to inflate the chest while supine at high G loads. This problem may be offset through the use of positive pressure breathing for G (PBG), although the effects of the thoracic counter pressure provided by a COMBat EDGE jerkin while supinated have yet to be determined.

While results of the self assessment of breathing difficulty did not produce significant differences, it is felt that the subjects did not receive adequate training in the use of the Borg scale. For example, when subject S2 could not catch his breath while flying a high-G supine turn, he reported that his breathing difficulty was only a 5 (strong effort), whereas if a subject could at best pant, he should have rated his difficulty at 9 or 10 (maximal respiratory effort). Possibly the use of different verbal descriptors should be used in future respiratory effort assessments.

There were few statistically significant differences in flight performance during all three phases of the ILS landing referable on body position or effects of motion. No significant differences related to body position or motion were found for ILS performance grades. When differences were found, these were primarily due to the difference in the index of flight experience.

In conclusion, high performance supine flight is feasible and additional study is warranted. Performance was definitely influenced and was reportedly more realistic under dynamic conditions. Certain aspects of the cockpit design which proved deficient could only

have been found while exposed to acceleration stresses. An objective set of criteria for evaluation of flight performance for individual flight maneuvers has been established. The method can easily be expanded for other well defined flight maneuvers under simulated and actual flight conditions. The implications for enhanced realism in training for high performance flight under normal and emergency conditions using such a dynamic flight simulator are obvious.

Future studies will include both form and fit studies, looking at the effects of different head and shoulder angles, use of advanced protective gear, such as USN EAGLE and PBG, different types of restraint, center vs side stick and display modifications, including a HDD (Head Down Display) and head mounted visual displays. Analysis of the respiratory data during the high-G turns and flight performance of the Half Cuban Eight and the Vertical S-2 maneuvers are currently underway.

REFERENCES

1. Cohen MM. Combining techniques to enhance protection against high sustained accelerative forces. Aviat. Space Environ. Med. 1983; **54**:338-42.

2. Gell CF, Hunter HN. Physiological investigation of increasing resistance to blackout by progressive backward tilting to the supine position. J. Aviat. Med. 1954; **25**:568-77.

3. Hrebien L, Hendler E. Factors affecting human tolerance to sustained acceleration. Aviat. Space Environ. Med. 1985; **56**:19-26.

4. von Beckh HJ. The development and airborne testing of the PALE seat. NADC Report No. NADC-81200-60, Warminster:Naval Air Development Center, 20 June 1981.

5. Cohen E. Is motion needed in flight simulators used for training? Human Factors. 1970; **12**:75-79.

6. Jacobs RS, Williges RC, Roscoe SN. Simulator motion as a factor in flight-director display evaluation. Human Factors. 1973; **15**:569-82.

7. Hubert JA, Alexander KK, Pickl WG. Concept development of a canopy escape module. AFWAL Technical Report No. AFWAL-TR-88-3049, Ohio:Wright Patterson Air Force Base, May 1988.

8. NATOPS Instrument Flight Manual (NAVAIR 00-80T-112, 1 April 1986)

9. NATOPS Flight Manual Navy Model F/A-18A/B/C/D (A1-F18AC-NFM-000, 15 September 1988).

10. Borg GAV. Psychophysical bases of perceived exertion. Medicine and Sci. in Sports and Exercise. 1982; 14: 377-81.

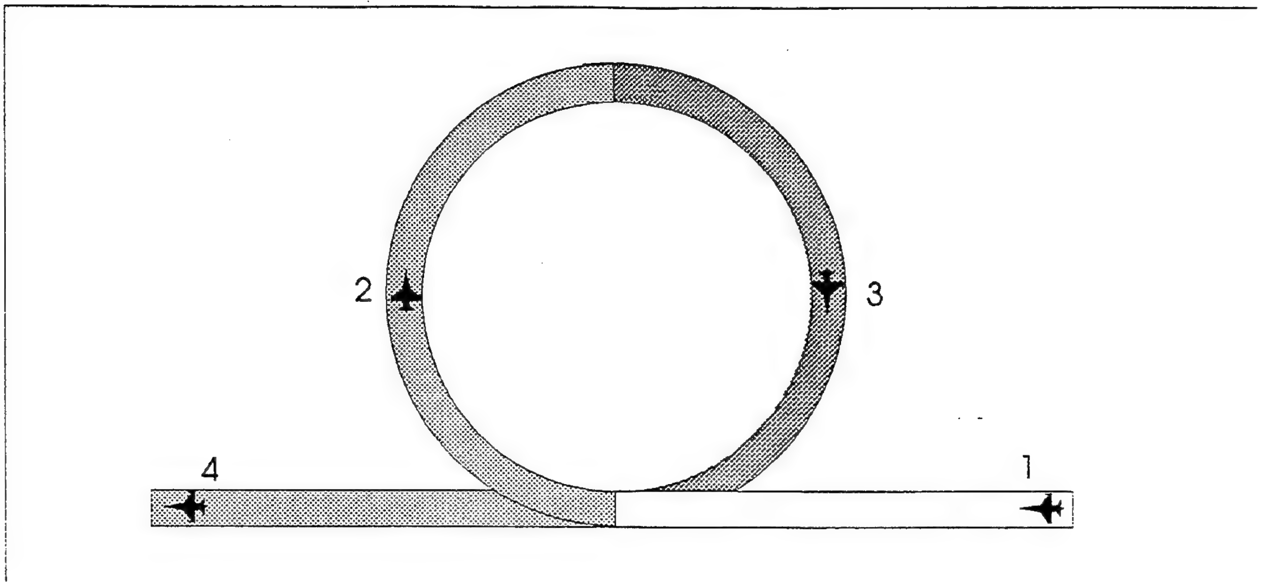


Figure 1. Modified Vertical S2 Maneuver. This uses the standard S2 maneuver with twice the standard rate turn instead of a half standard rate turn. Segment 1 is 15 s of straight and level flight, Segment 2 is a descending 180° right turn, Segment 3 is an ascending 180° right turn followed by Segment 4 which is again 15 s of straight and level flight. The exit heading is the same as the entry heading.

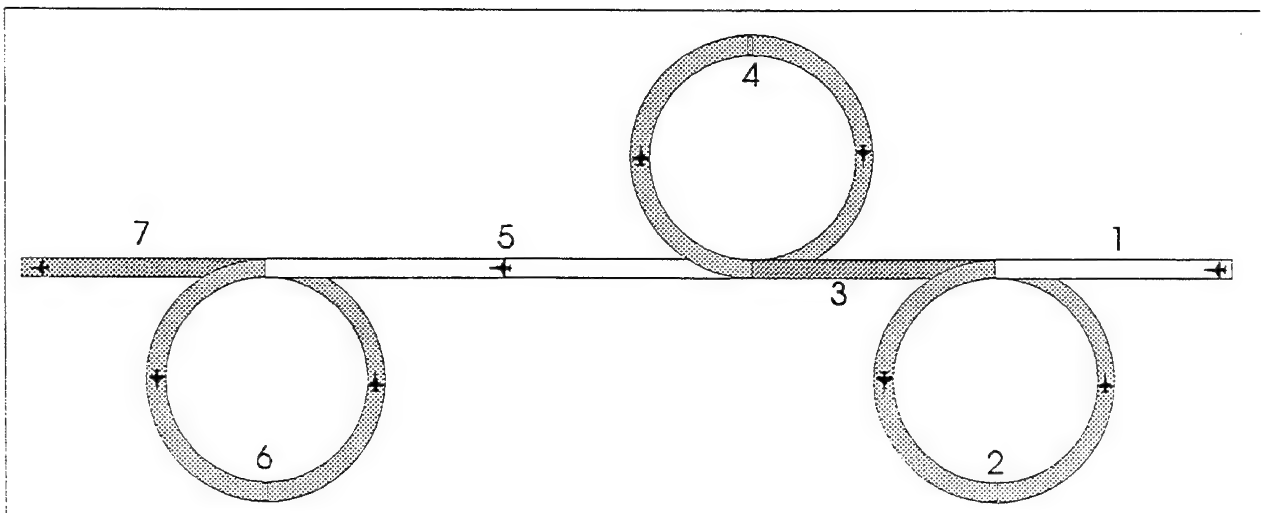


Figure 2. The High-G Turn Maneuvers (Oscar Pattern) are based on the standard Oscar pattern, but substituting constant acceleration turns for the standard rate turns. The segments are as follows: 1: 15 s straight and level flight; 2: "low" G 360° left turn; 3: 45 s straight and level flight; 4: "medium" G 360° right turn; 5: 60 s straight and level flight; 6: "high" G 360° left turn; 7: 15 s straight and level flight. The exit heading is the same as the entry heading.

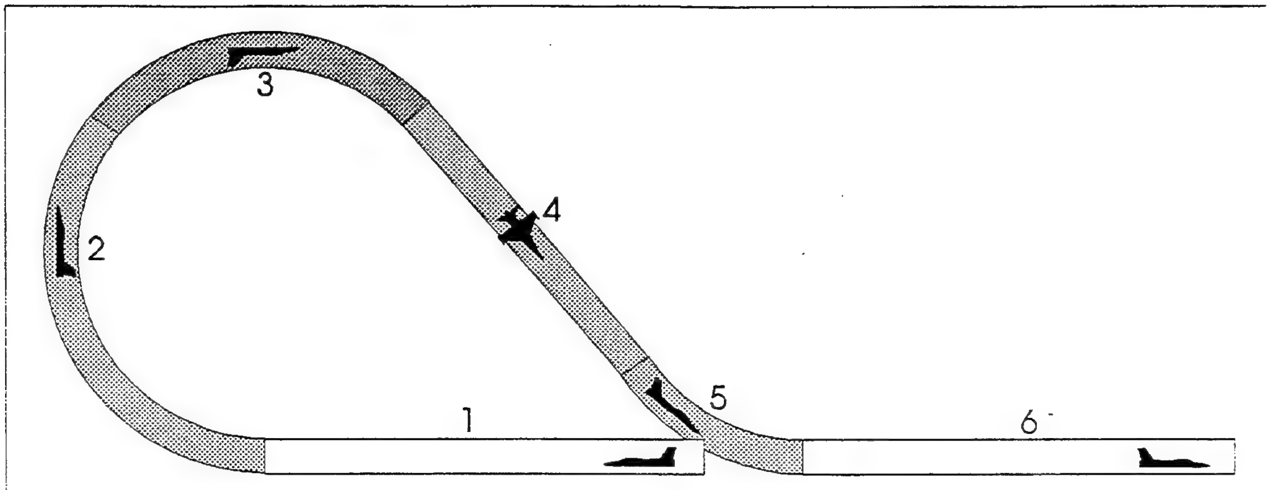


Figure 3. The Half Cuban Eight Maneuver is a standard maneuver. Its segments can be broken down as follows: 1: 15 s straight and level flight; 2: constant G pull up until 10° angle of attack (α); 3: hold that 10° α until the end altitude is achieved (about 13,000 ft) with a 45° inverted nose low attitude; 4: then roll upright; 5, with a constant G pullout achieve a 180° course reversal at entrance altitude; 6: then end the maneuver with 30 s straight and level flight.

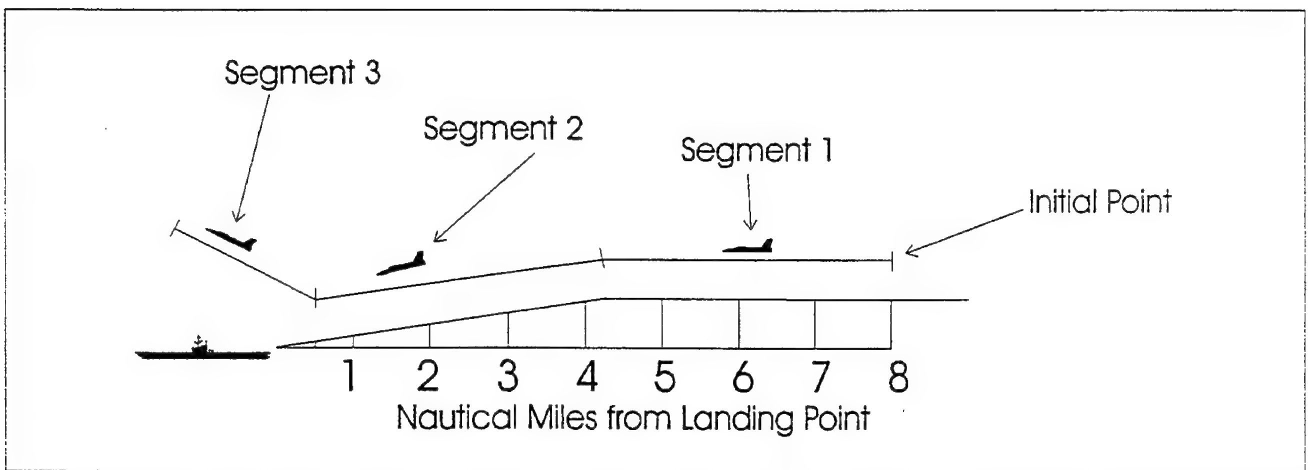


Figure 4. The ILS task begins when the subject brings the aircraft to an altitude of 1,200 ft, then the ILS indicators are activated and the aeromodel automatically places the nose of the aircraft 8 nm from the runway. In Segment 1, the aircraft is flown straight and level at 1,200 ft while configuring for landing until 4.3 nm from the runway. Then, for the final approach (Segment 2) the aircraft is pushed over when it intercepts the glide slope which it follows until it reaches the inner ILS marker (3,900 ft from the runway at 200 ft above ground level). At this point, a missed approach maneuver is initiated in which the aircraft is waved off for 30 s (Segment 3).

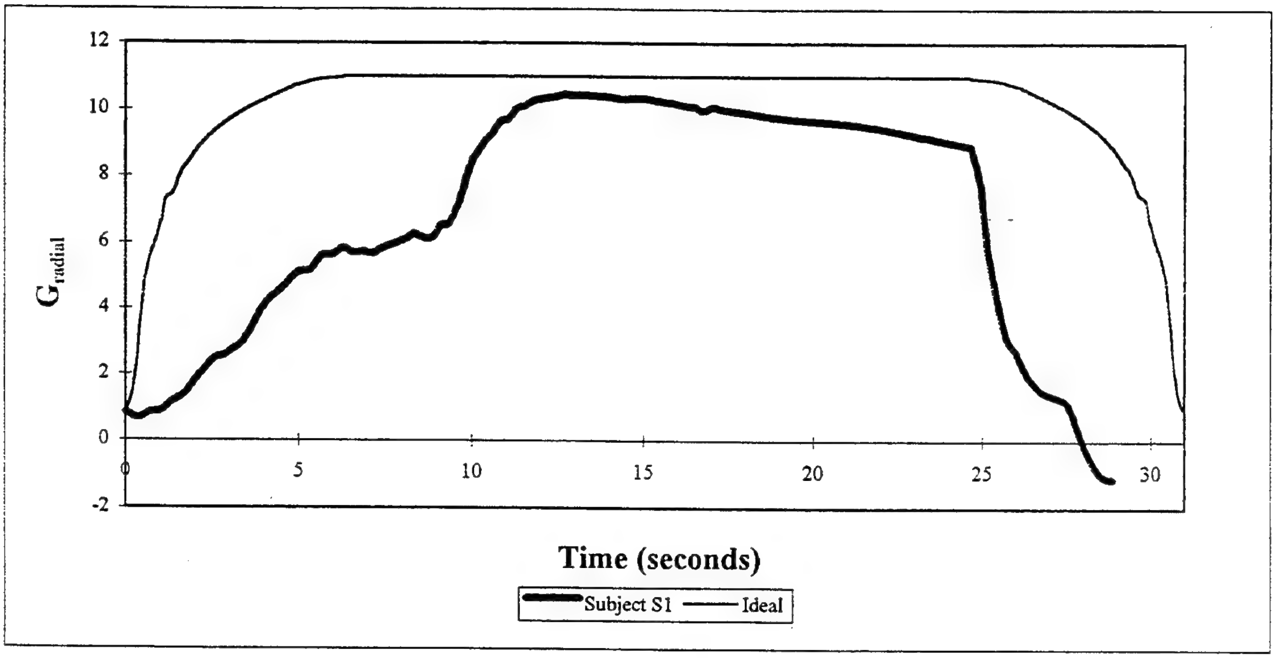


Figure 5. Example of 11 G_{radial} turn performance while supine for Subject S1 as compared to the Ideal profile.

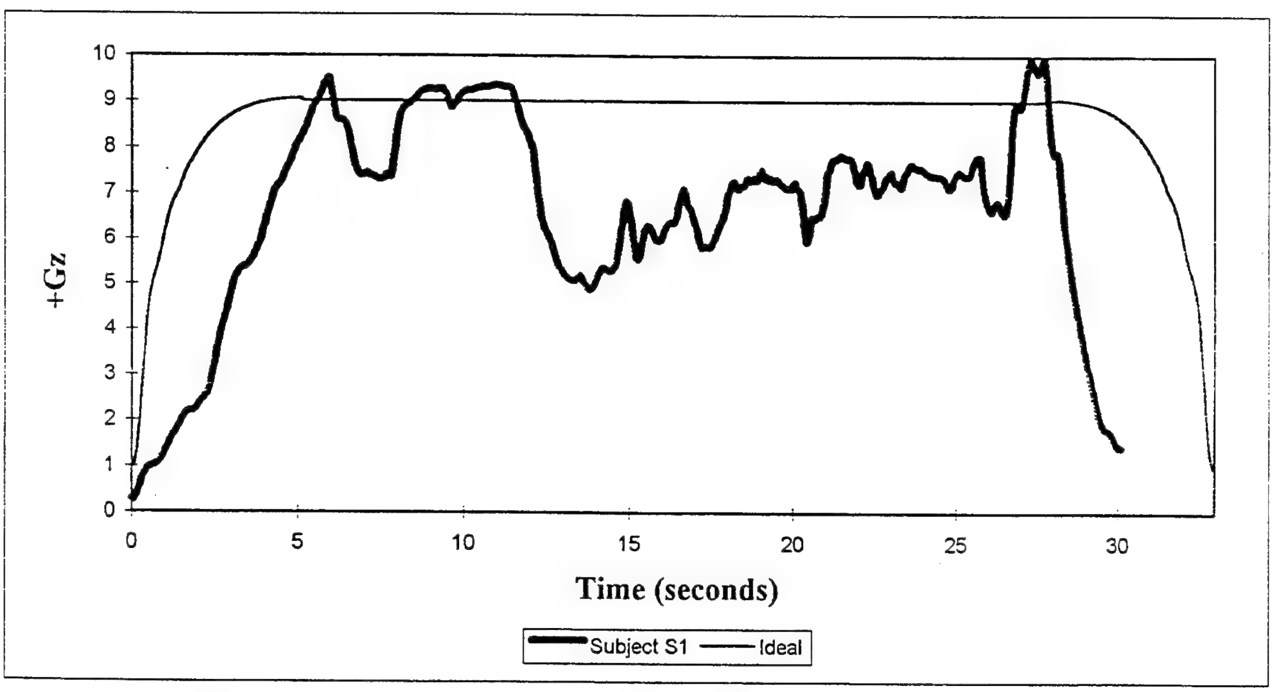


Figure 6. Example of +9 Gz turn performance while upright for Subject S1 as compared the to Ideal profile.

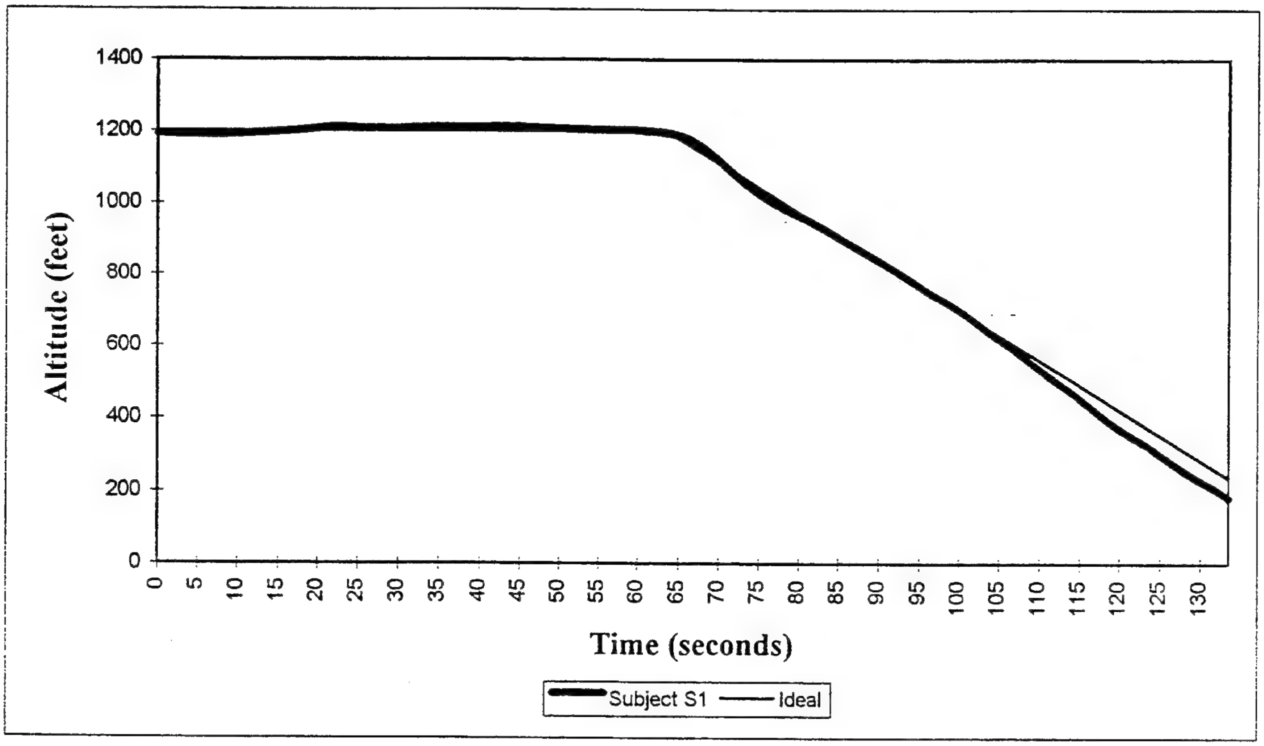


Figure 7. Example of ILS performance while supine for Subject S1 as compared to the Ideal profile.

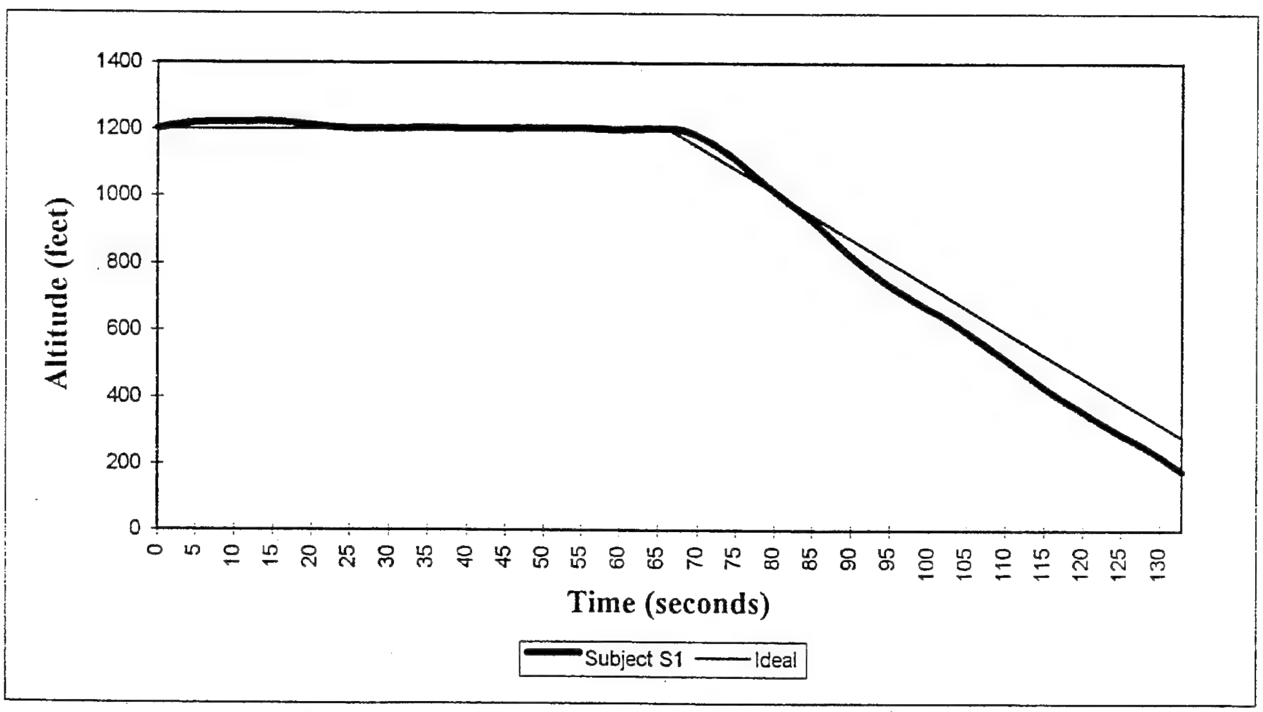


Figure 8. Example of ILS performance while upright for Subject S1 as compared to the Ideal profile

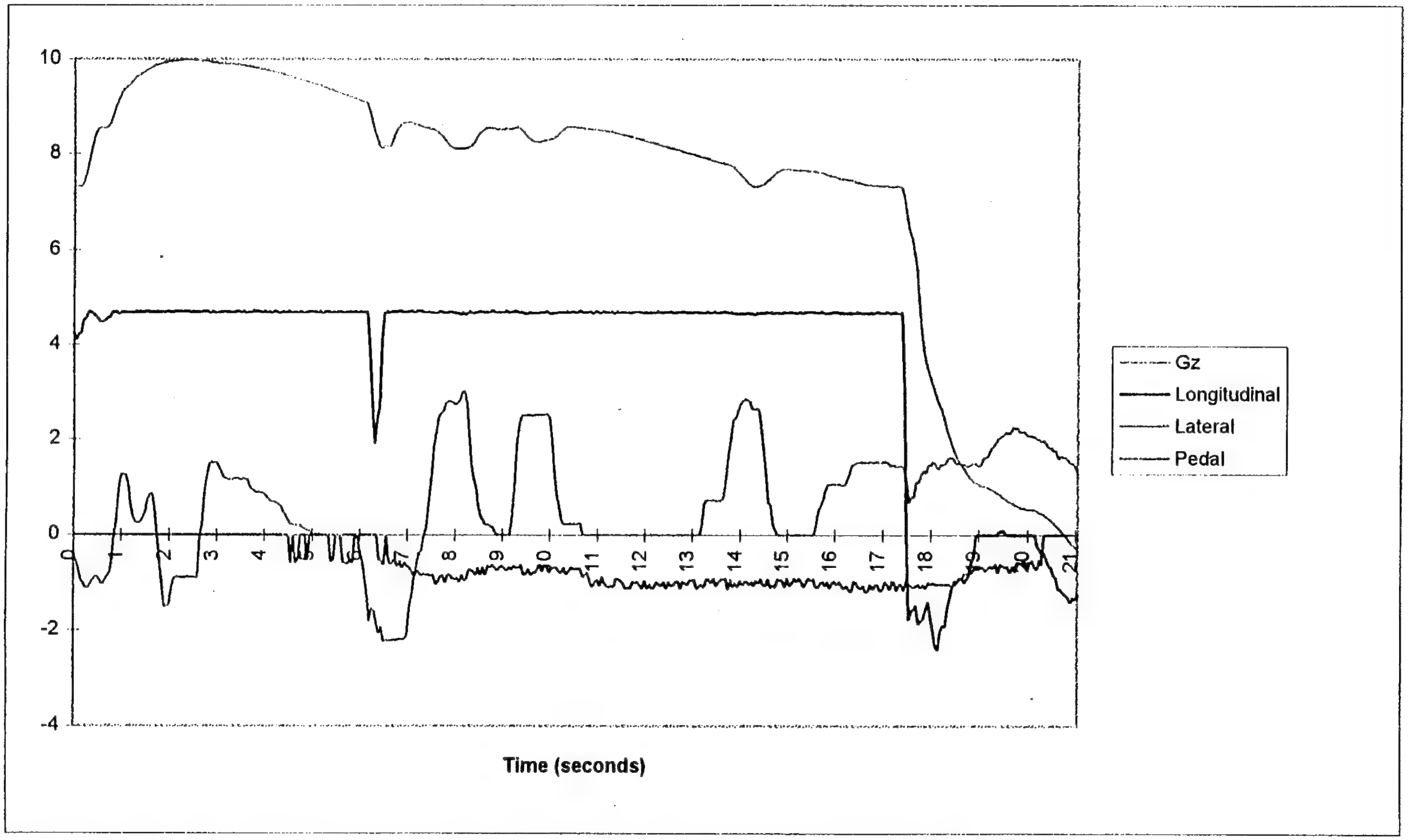


Figure 9. Control stick and rudder pedal movements during Subject S2 +11 Gz supine turn prior to a loss of consciousness episode. Gz is in G units (multiples of 9.8 m/s^2), longitudinal and lateral stick and rudder pedal values are in arbitrary units. Negative lateral and pedal values indicate left inputs, positive longitudinal values indicate forward direction.

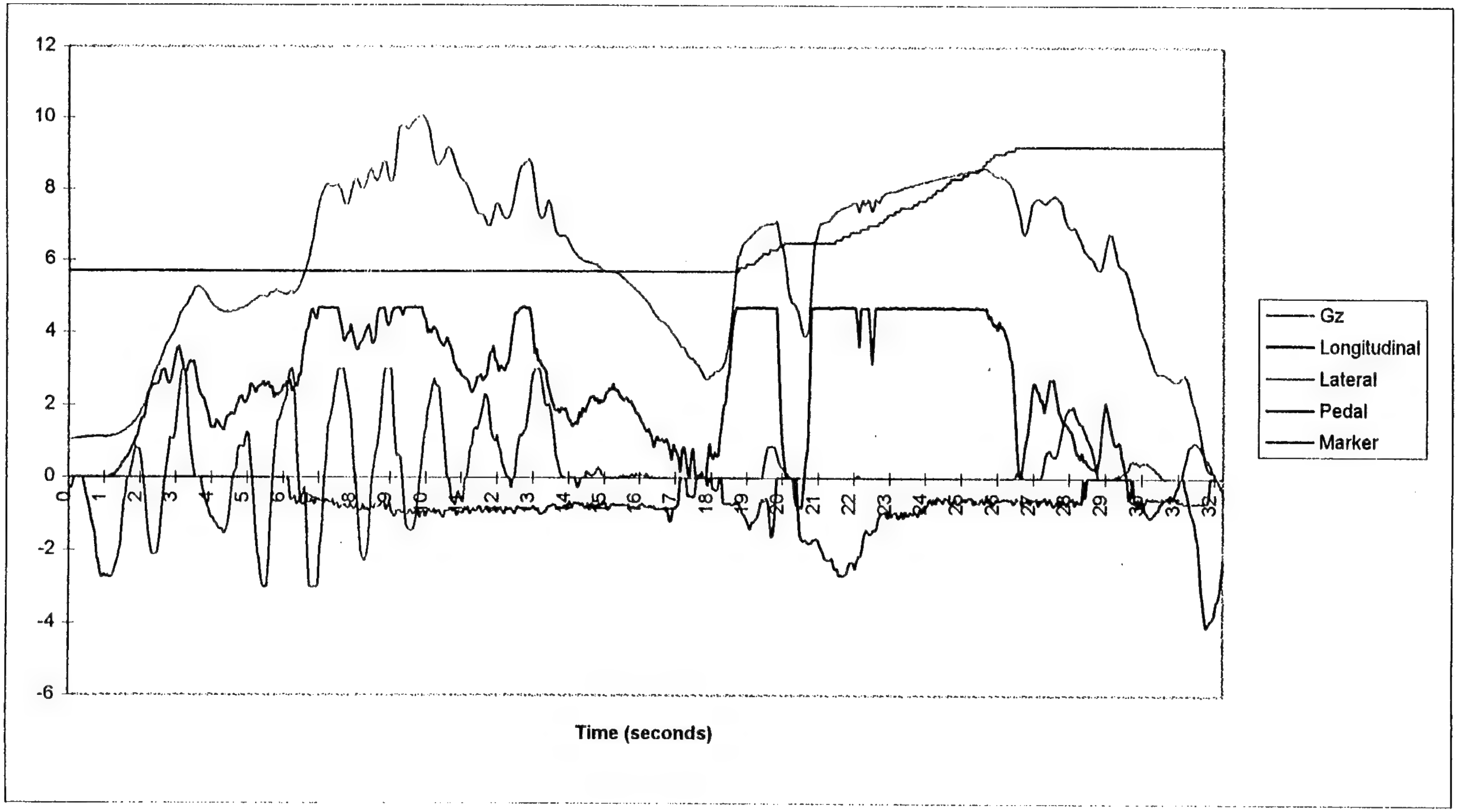


Figure 10. Control stick and rudder pedal movements during Subject S2 +11 Gz supine turn during almost loss of consciousness episode. Gz is in G units (multiples of 9.8 m/s^2), longitudinal and lateral stick and rudder pedal values are in arbitrary units. Negative lateral and pedal values indicate left inputs, positive longitudinal values indicate forward direction. Marker values indicate possible involuntary right hand inputs.

APPENDIX A

G TURN DATA

KEY:

Time in seconds
+Gz in multiples of 9.8 m/s^2
Airspeed in KCAS
Altitude in feet
Heading in degrees

Onset is defined from the beginning of the maneuver to the first peak in +Gz

Offset is defined from the end of the plateau of the turn to the first increase in +Gz

(NOTE: Due to the large quantity of data tables, this appendix is available in a separate technical report. The data may also be obtained by writing to

Human Performance Technology Branch
Naval Air Warfare Center Aircraft Division Warminster
ATTN: Barry S. Shender, Ph.D. (Code 464100R15)
P.O. Box 5152
Warminster, PA 18974-0591)

APPENDIX B

ILS MANEUVER DATA

KEY:

Time in seconds
Airspeed in KCAS
Altitude in feet
Heading in degrees
Vertical Airspeed or climb rate (V. Speed) in feet/second

ILS Approach is defined from the beginning of the maneuver to the change in altitude slope or when the event marker was pressed

ILS Decision point occurs when climb rate and/or the throttle starts increasing or when the event marker was pressed

(NOTE: Due to the large quantity of data tables, this appendix is available in a separate technical report along with Appendix A. The data may also be obtained by writing to

Human Performance Technology Branch
Naval Air Warfare Center Aircraft Division Warminster
ATTN: Barry S. Shender, Ph.D. (Code 464100R15)
P.O. Box 5152
Warminster, PA 18974-0591)

APPENDIX C

QUESTIONNAIRE

SUPINE CREW STATION CONCEPT EVALUATION DURING CLOSED LOOP DYNAMIC FLIGHT SIMULATION

Thank you for participating in the project "Supine Crew Station Concept Evaluation During Closed Loop Dynamic Flight Simulation." This questionnaire is your opportunity to provide your subjective assessment of the supine cockpit. Your opinions are every bit as important as the data we collected during your static and dynamic runs in the DFS. Please read each question carefully and indicate your response by circling the appropriate alternative or supplying the appropriate information.

COMFORT ASSESSMENT

1. Rate the level of discomfort experienced in your **right arm** (control stick):

0 No pain	1 slight	2	3 moderate	4	5 severe

2. Rate the level of discomfort experienced in your **left arm** (throttle):

0 No pain	1 slight	2	3 moderate	4	5 severe

3. Rate the level of discomfort experienced in your **head**:

0 No pain	1 slight	2	3 moderate	4	5 severe

4. Rate the level of discomfort experienced in your **neck**:

0 No pain	1 slight	2	3 moderate	4	5 severe

5. Rate the level of discomfort experienced in your **chest**:

0 No pain	1 slight	2	3 moderate	4	5 severe

6. Rate the level of discomfort experienced in your **abdomen**:

0 No pain	1 slight	2	3 moderate	4	5 severe

7. Rate the level of discomfort experienced in your **legs**:

0 No pain	1 slight	2	3 moderate	4	5 severe

8. Indicate whether you felt that there was **sufficient** or **insufficient padding** on the seat:

head:	upper back:	lower back:	seat pan:
sufficient insufficient	sufficient insufficient	sufficient insufficient	sufficient insufficient

9. Rate the ability of the **harness** to effectively hold you into the seat:

1 poor	2	3 average	4	5 excellent

10. Assess how well the **calves** of your **anti-G suit** inflated:

1 severely impeded	2	3 moderately impeded	4	5 unimpeded

11. Assess how well the **thighs** of your **anti-G suit** inflated:

1 severely impeded	2	3 moderately impeded	4	5 unimpeded

12. Assess how well the **abdomen** of your **anti-G suit** inflated:

1 severely impeded	2	3 moderately impeded	4	5 unimpeded

14. Did your **anti-G suit supply hose kink** during maneuvers?

YES **NO**

VISION ASSESSMENT

15. Rate your ability to see the **HUD**:

1 severely impeded	2	3 moderately impeded	4	5 clear view

16. Rate your ability to see the **left 19" monitor**:

1 severely impeded	2	3 moderately impeded	4	5 clear view

17. Rate your ability to see the **center 19" monitor**:

1 severely impeded	2	3 moderately impeded	4	5 clear view

18. Rate your ability to see the **right 19" monitor**:

1 severely impeded	2	3 moderately impeded	4	5 clear view

20. List in the space below what, if anything, impeded your vision.

REACH ASSESSMENT

21. Rate your ability to reach the **throttle**:

1 poor	2	3 average	4	5 excellent

22. Rate your ability to reach the **switches** on the **throttle**:

1 poor	2	3 average	4	5 excellent

23. Rate your ability to reach the **control stick**:

1 poor	2	3 average	4	5 excellent

24. Rate your ability to reach the **switches** on the **control stick**:

1 poor	2	3 average	4	5 excellent

25. Rate your ability to reach the **rudder pedals**:

1 poor	2	3 average	4	5 excellent

26. Indicate in the area below anything else that you needed to reach, but could not.

FLYING ASSESSMENT

27. Rate your ability to fly the **VERTICAL S-2** in the **UPRIGHT** position:

1 poor	2	3 average	4	5 excellent

28. Rate your ability to fly the **VERTICAL S-2** in the **SUPINE** position:

1 poor	2	3 average	4	5 excellent

31. Rate your ability to fly the **HIGH-G TURNS (OSCAR)** in the **UPRIGHT** position:

1 poor	2	3 average	4	5 excellent

32. Rate your ability to fly the **HIGH-G TURNS (OSCAR)** in the **SUPINE** position:

1 poor	2	3 average	4	5 excellent

33. Rate your ability to fly the **HALF CUBAN EIGHT** in the **UPRIGHT** position:

1 poor	2	3 average	4	5 excellent

34. Rate your ability to fly the **HALF CUBAN EIGHT** in the **SUPINE** position:

1 poor	2	3 average	4	5 excellent

35. Rate your ability to fly the **ILS MANEUVER** in the **UPRIGHT** position:

1 poor	2	3 average	4	5 excellent

36. Rate your ability to fly the **ILS MANEUVER** in the **SUPINE** position:

1 poor	2	3 average	4	5 excellent

37. Given that the aeromodel is based on a "generic high performance aircraft," did you feel that the flight characteristics of the DFS were "airplane-like?"

1 not at all	2	3 somewhat	4	5 absolutely

38. Based on the amount of static training you had flying the syllabus, indicate how well prepared you actually were for closed loop flying in the DFS.

1 not at all	2	3 somewhat	4	5 absolutely

39. Describe the level of your flying experience, including type(s) of aircraft, hours, rating, etc.

40. What modifications to the flight simulation capabilities of the DFS would you recommend that would make it more realistic?

41. List any additional display information you would like available in order to fly supine. Indicate whether that information would be displayed on the HUD or on a HDD.

42. List any modifications in the supine cockpit you would like to have to enhance your comfort.

43. List any modifications you would recommend to the controls that would enhance your ability to fly supine.

44. Please give us your overall impression of flying in a supine position.

DISTRIBUTION LIST

	No. of Copies
Director Defense Technical Information Center Bldg. 5, Cameron Station Alexandria, VA 22314	1
Commander, Naval Air Systems Command Naval Air Systems Command Headquarters Code AIR-320R Washington, D.C. 20361-0001	1
Commander, Naval Air Systems Command Naval Air Systems Command Headquarters Code AIR-531TA Washington, D.C. 20361-0001	1
Commander, Naval Air Systems Command Naval Air Systems Command Headquarters Code AIR-5311D Washington, D.C. 20361-0001	1
Office of Naval Research Bioscience Division Arlington, VA 22217-5000	2
Commanding Officer Naval Medical Research & Development Command Naval Medical Command National Capital Region Bethesda, MD 20814	1
Commanding Officer Naval Medical Research & Development Command Naval Medical Command National Capital Region Code NMRDC-44 Bethesda, MD 20814	1
Chief, Bureau of Medical & Surgery Navy Department Washington, D.C. 20372	1
Chief, Bureau of Medical & Surgery Navy Department Code NM&S 3C1 Washington, D.C. 20372	1

Chief of Naval Operations
Navy Department
Washington, D.C. 20350-2000 1

Chief of Naval Operations
Navy Department
Code N-88
Washington, D.C. 20350-2000 1

Commander
Naval Safety Center
Naval Air Station
Norfolk, VA 23511 1

Commanding Officer
Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, FL 32508 1

Commanding Officer
Naval Aerospace Medicine Institute
Naval Air Station
Pensacola, FL 32508 1

Superintendent
Naval Postgraduate School
Monterey, CA 93943 1

Commanding Officer
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92138... 1

Commanding Officer
Naval Air Warfare Center
Patuxent River, MD 20670 1

Commanding Officer
AL/CFBS, ATTN: B. Albery
Wright-Patterson AFB, OH 45433-6573 1

Commanding Officer
AL/CFTF, ATTN: J. Burns
Brooks AFB, TX 78235 1

Commanding Officer
US Army Aerospace Medical Research Laboratory
ATTN: Technical Library
Fort Rucker, AL 36362-5295 1

Naval Air Warfare Center Aircraft Division Warminster 21
(20 copies for Code 4.6.4.1)
(1 copy for Code 7.2.5.5)